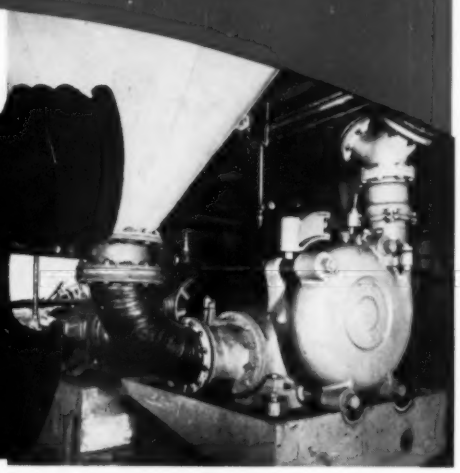
MINING engineering

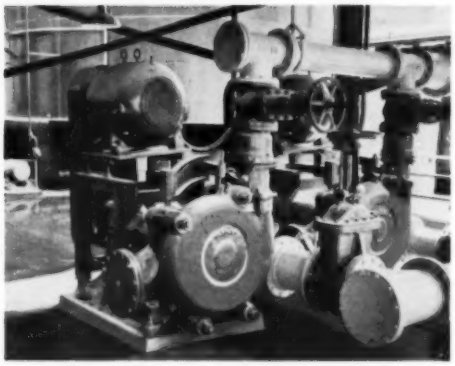
OCTOBER 1959

WILFLEY SAND PUMPS



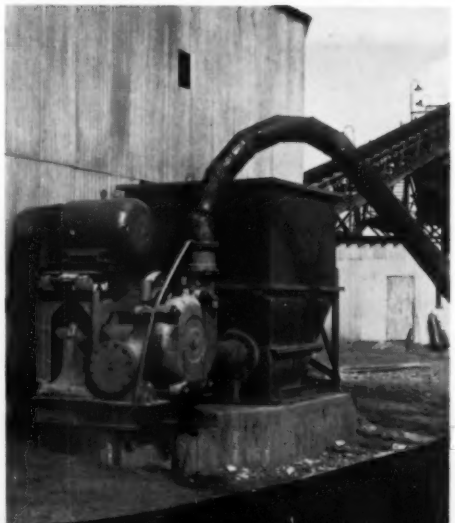
Versatility

to Solve Your SPECIFIC Pumping Problems



Every year the applications for Wilfley Sand Pumps become more varied. So **many** industries now require low cost pumping of sand, slimes, slurries—abrasive solutions of all types. Wilfley Sand Pumps are designed to meet all requirements in the transfer of solids. They may be fitted with interchangeable electric furnace alloy iron, special application alloys, or rubber-covered wear parts. Whether you need belt driven, overhead V-belt driven, or direct driven pumps, Wilfley has them—available in **1", 1½", 2", 2½", 3", 4", 5", 6", 8"** and **10"** discharge sizes with capacities to 3600 GPM and heads as high as 200′.

This all-around versatility plus continuous, maintenance-free performance and longer pump life make Wilfley the No. 1 choice of economy-minded plant operators throughout the world. To give you maximum economy in solids pumping, every Wilfley installation is **Job Engineered.**



Write, wire or phone for complete details.

Wilfley Sand Pumps
"Companions in Economical Operation"
Wilfley Acid Pumps

A. R. WILFLEY and SONS, INC.

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COMING EVENTS

Oct. 12-14, 8th National Clay Conference, sponsored by Clay Minerals Committee, National Academy of Science—National Research Council, University of Oklahoma, Norman, Okla.

Oct. 15, AIME Utah Section, "Operating Problems Involved in Drilling, Shaft Sinking and Mining in the New Mexico Ambrosia Lake Region," by Victor L. Stevens, Newhouse Hotel, Salt Lake City.

Oct. 16-17, Illinois Mining Inst., 67th annual meeting, Oct. 16, Hotel Abraham Lincoln, Springfield, Ill.; Illinois vs Minnesota football game, Oct. 17, Champaign, Ill.

Oct. 19-21, Congress, Mining Section, National Safety Council, Congress Hotel, Chicago.

Oct. 27-29, 1959 AIME-ASME Joint Solid Fuels Conference, Netherland-Hilton Hotel, Cincinnati.

Oct. 28-31, International Mining Days and New Mexico Mining Assn., annual meeting, Paso del Norte Hotel, El Paso, Texas

Oct. 30-31, AIME Central Appalachian Section and West Virginia Coal Mining Inst., annual meeting, The Greenbrier, White Sulphur Springs, W. Va.

Nov. 3, AIME Chicago Section, ladies' night, Morrison Hotel, Chicago.

Nov. 5, American Mining Congress, Coal Div. Conference, Penn-Sheraton Hotel, Pittsburgh.

Nov. 6, AIME Pittsburgh Section and NOHC Pittsburgh Section, 14th annual Off-the-Record Meeting, Penn-Sheraton Hotel, Pittsburgh.

Nov. 9-12, Society of Exploration Geophysicists, annual meeting, Biltmore Hotel, Los Angeles.

Nov. 19, AIME Utah Section, "Geology of Anaconda's Chuquicamata Mine" by G. C. Waterman, Newhouse Hotel, Salt Lake City.

Nov. 19-20, Missouri School of Mines, 5th Symposium on Mining Research: ammonium nitrate explosives, field performance, safety, Missouri School of Mines, Rolla, Mo.

Nov. 30, American Mining Congress, annual membership meeting, Plaza Hotel, New York.

Dec. 4, AIME Lehigh Valley Section, ladies' night.

Dec. 5, AIME Knoxville Area Subsection, Southeast Section, annual Christmas Party, C'est Bon Restaurant, Knoxville, Tenn.

Dec. 6, 7, AIME Arizona Section, annual meeting, Speaker: J. L. Gillson; Tucson, Ariz.

Dec. 10, AIME Chicago Section, students' night.

Dec. 10, AIME Oregon Section, J. L. Gillson, speaker; Portland, Ore.

Dec. 12, AIME Montana Section, annual meeting, J. L. Gillson, speaker; Butte, Mont.

Jan. 11, 1960, AIME Minnesota Section, annual meeting, J. L. Gillson, speaker; Duluth.

Feb. 14-18, AIME Annual Meeting, Hotels Statler and Sheraton-Atlantic, New York.

Feb. 16-17, 10th annual California Statewide meeting, Governor's Industrial Safety Conference, Fairmont Hotel, San Francisco.

Feb. 16-19, Australasian Inst. of Mining and Metallurgy, Symposium on Hydrometallurgy, "Wet Processing of Minerals and Industrial Products," Adelaide, Australia.

Apr. 6-9, International Mineral Processing Congress, sponsored by The Institution of Mining and Metallurgy, Church House, Westminster, London, England.

Apr. 21-22, AIME Pacific Southwest Regional Metals and Minerals Conference, Ambassador Hotel, Los Angeles.

Apr. 28-30, AIME Pacific Northwest Regional Conference, Sheraton Hotel, Portland, Ore.

May 9-11, American Mining Congress, Coal Convention, Pittsburgh.

July 11-18, 2nd World Conference on Earthquake Engineering, organized by Science Council of Japan in cooperation with Japan Soc. of Civil Engineers, Architectural Inst. of Japan, Seismological Soc. of Japan; Tokyo and Kyoto, Japan.

Oct. 5-7, AIME Rocky Mountain Minerals Conference, Utah Section host, Newhouse Hotel, Salt Lake City.

MINING engineering

Vol. 11 NO. 10 **OCTOBER 1959**

COVER *In any enterprise, whether it be in the minerals industry or any other, the costs of replacing, or not replacing capital equipment are major economic factors—and problems. Artist Herb McClure has tied this month's cover to the article on page 1003, in which are discussed methods of systematic equipment replacement used by an open pit mining company.*

PALEY REPORT

1006 **Copper, Lead, and Zinc—Predictions and Experience** • *Evan Just*

TECHNICAL ARTICLES

1003 **Replacement of Capital Equipment** • *H. J. Schwellenbach*

1008 **Stockpiling: Purposes—Methods—Tools** • *L. O. Millard*

1015 **Self-Fluxing Sinter** • *T. E. Ban, C. D. Thompson, and C. A. Czako*

1022 **The Shear Strength of Rocks** • *R. G. Wuerker*

1027 **Deflection of Mine Roof Supports** • *Lawrence Adler*

1030 **Relation of Land Subsidence to Ground-Water Withdrawals in the Upper Gulf Coast Region, Texas** • *A. G. Winslow and L. A. Wood*

1035 **Electronic Computer and Statistics for Predicting Ore Recovery** • *R. F. Shurtz*

1045 **Fishing Tools for Retrieving Gamma-Ray Logging Components** • *C. M. Bunker and J. M. Ohm*

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1049 **SME Bulletin Board: Your Guide for Society, Professional News**

MINING ENGINEERING staff, Society of Mining Engineers, and AIME Officers are listed on the *Drift* page.

Address insertion orders and copy to MINING ENGINEERING, 29 W. 39th St., New York 18, N. Y. Send plates to: MINING ENGINEERING, c/o Lew A. Cummings Co. Inc., 215 Canal St., Manchester, N. H. Published monthly by the American Institute of Mining, Metallurgical, and Petroleum Engineers, Inc., 29 W. 39th St., New York 18, N. Y. Telephone: PEnnsylvania 6-9220; TWX NY 1-1304. Subscription $8 per year for non-AIME members in the U. S., & North, South, & Central America; $10 foreign; $6 for AIME members, or $4 additional for members only in combination with a subscription to "Journal of Metals" or "Journal of Petroleum Technology". Single copies, $.75; single copies foreign, $1.00; special issues, $1.50 AIME is not responsible for any statement made or opinion expressed in its publications.

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PERSONNEL

THESE items are listings of the Engineering Societies Personnel Service Inc. This Service, which cooperates with the national societies of Civil; Electrical; Mechanical; Mining, Metallurgical, and Petroleum Engineers, is available to all engineers, members and nonmembers, and is operated on a nonprofit basis. If you are interested in any of these listings, and are not registered, you may apply by letter or resume and mail to the office nearest your place of residence, with the understanding that should you secure a position as a result of these listings you will pay the regular employment fee of 5 pct of the first year's salary if a nonmember, or 4 pct if a member. Also, that you will agree to sign our placement fee agreement which will be mailed to you immediately, by our office, after receiving your application. In sending applications be sure to list the key and job number. When making application for a position, include 8¢ in stamps for forwarding application to the employer and for returning when possible. A weekly bulletin of engineering positions open is available at a subscription rate of $3.50 per quarter or $12 per annum for members, $4.50 per quarter or $14 per annum for nonmembers, payable in advance. Local offices of the Personnel Service are at 8 W. 40th St., **New York 18;** 57 Post St., **San Francisco;** 29 E. Madison St., **Chicago 1.**

MEN AVAILABLE

Geologist, age 22, B.S. in geology, married. Desires position in mining, oil, gas, or ground water industry. M-510.

Mine Manager or Superintendent, M.E. degree, age 51, registered engineer. Thirty years in metal mining including nine as mine superintendent, flotation, and cyanide milling knowledge. Prefer Latin America. M-505.

Production Manager, with 12 years experience, 6 as division production manager of mining and process operation; complete responsibility for $2 million per year operation. M.S. and B.S. in chemical engineering at M.I.T. Experience also includes research, development of major new process, pilot plant design and operation, and design and construction supervision of new process plant. M-506.

Geologist, B.S., age 25; two years experience, one in Brazil as assistant party chief. Iron and base metal experience; knowledge of ore reserves, surface and underground mapping, sampling, etc. Location, anywhere. M-507.

Geological Engineer, M.S., 25, single. Three years experience as instrument operator and computor with seismic crew, now desires to be established in mineral exploration field. Thesis experience in photogeology. Foreign positions acceptable. M-508.

Mine Superintendent-Plant Superintendent, graduate E.M., age 33, married. Nine years experience underground hard rock mine and plant supervision and engineering. Background includes production planning, forecasting and scheduling; project engineering; operations and engineering surveys; mine safety and legal compliance; equipment installation and maintenance; supervision; training. Will relocate in U. S., preferably northeast. M-509.

Position Desired as Sales-Service-Consulting, B.S. in civil engineering, age 49. Experience in general highway engineering, all operations. Eight years experience in maintenance and construction of concrete structures. Twenty-two years experience in all types of structures. Prefer Midwest. M-985-Chicago.

Geologist-Mining, Petroleum, age 33. Four years in charge of exploration and development, underground and surface, mapping, diamond drilling, milling for mining companies. $500. Prefer Mexico, will consider anywhere. S(M)-1438.

Superintendent-Mining, Allied, E.M., age 55. Thirty years experience in planning, supervising production, mine examination, exploration and development programs on mining, petroleum, and metallurgy. $700. Prefer U. S. S(M)-221.

Junior Engineer, Sales-Mining, Heavy Equipment, E.M., age 24. Nine months spent as sampler, surveyor, working on plane table, stake claims, assessment for mining and exploration company. Salary, open. Any location. S(M)-197.

Superintendent, Research-Milling, Mining, metallurgical engineer, age 47. Four years experience supervising contract mining, milling, exploration, on manganese mine and mill. Ten years as mill superintendent in lead, zinc, asbestos. Six years in research on Pb-Zn-Cu-Ag ores, mining chemistry. $700; prefer West, U.S. S(M)-1826.

Geologist—Petroleum, Gas, Mining: Geolgist, mining engineer, age 44. Spent 6½ years in exploration and development, geological and geophysical investigations for oil and gas companies. Exploration and drilling for uranium deposits, analysis and correlation, maps, reports for oil company. $800. Prefer California, West. S(M)-1788.

Construction Manager Estimater-Construction, Mining, Mechanical, mining engineer, age 46. Six years spent as chief estimator, manager, doing estimating mechanical work in process, metal, chemical, petroleum, missile, cement steel industries, for mechanical contractors. Construction superintendent for 3½ years, responsible for checking estimates, coordinating office and field, for construction companies. Four years project engineer and mine superintendent responsible for sinking shaft, building plant utilities, mining program for heavy chemical company. $850. Prefer San Francisco Bay Area. S(M)-1760.

Superintendent, Foreman—Mining engineer, age 35. Two years grade, tonnage control, some design for new installation on open pit copper mine. Four years mine superintendent on gold mining. Six years student and trainee in Pb-Zn and manganese mining. $725. Prefer U. S. or anywhere with schools for children. S(M)-1257.

Geologist—Minerals, Petroleum, Ceramics: M.S. in mining, geology, ceramics, age 29. Five years as geologist doing water resources, exploration, underground, open pit mine mapping on tungsten ores. Graduate research engineer for 2½ months studying leaching methods for deep sea manganese nodules, uses of manganese, cobalt, and nickel for university. Six months as topographic field assistant on geological survey. $500. Prefer West U. S. S(M)-1631.

Junior Mining Engineer, mining engineer, age 24. Teaching assistant for 2½ years, research assistant in mining engineering for a university. Three years in the Navy working on damage control (completed). $500 Prefer West U. S. S(M)-1614.

General Superintendent—Mine, mining, metallurgy, in Mexico, age 37. Eleven years assistant mining superintendent, general manager, assistant general superintendent on lead, copper, zinc mines and cyaniding flotation, heavy-media mills. Six months training in Mexico. $6000 (U. S. currency in Mexico.) S(M)-1556.

Superintendent, Manager-Mining, Ore Process, chemical engineer, age 46. Leased and operated Pb-Zn mine for 3½ years. For 6½ years was manager of operations, mine superintendent, plant, research metallurgist in vanadium ores, Pb-Zn, in charge of operations, mine development, facilities, and extraction for mining companies. $12,000. Prefer South America, U. S. S(M)-1349.

Ore dressing metallurgist to work on process development and mill control at a progressive mining operation. Liberal housing and employe benefits. Apply for application form to: **Box 9ME, AIME, 29 W. 39th St., New York 18, N. Y.**

POSITIONS OPEN

Consulting Engineer, metallurgical, under 45, with wide experience in copper smelting and refining and familiar with operations and engineering in various copper producing areas of the world. Will provide technical direction for metallurgical plant design and construction, provide technical assistance to operating smelters and refineries and handle development work for new methods. Must be top-notch man with broad experience. Some travel. Salary, open. Location, West. W7906.

Mining Engineer, with experience covering operations on manganese deposits in Latin America. Spanish essential. Salary, open. F7873.

Assistant Mine Superintendent, 30 to 45, with underground hard rock experience, to assist in supervision of all underground operations under direction of mine superintendent. Permanent. Salary, about $7000 year to start. Location, South. W7868.

Research Engineer, mineral beneficiation, research and process development on wide variety of industrial minerals. Several years experience preferred. Location Southeast. W7856.

Junior Engineers, or recent graduates, mining, for engineer trainees at open pit copper operations. Salary, open. Location, Southwest. W7840S.

Manager of Operations-General Superintendent, graduate mining engineer with open pit and mine experience. Also cost conscious, for quarry operators and producers of limestone. Salary, open. Location, South. W7832.

Engineers: a) Foundry Superintendent with experience in cast iron foundries. **b) Engineer** with cast iron foundry experience in production, design, etc. Location, northern New Jersey. W7774.

Quality Control Supervisor, for a nonmetallic mineral mine and at a white pigment plant. Job involves half time on quality control and half on any of plant engineering or geology or mine engineering or special assistance, depending on applicant. Salary $6000 to $7000 annually. Company will pay placement fee. Location, northeastern New York State. W7649.

Mining and Metallurgical Engineer, for open pit phosphate mining operations. Operation consists of hydraulic mining, washing, flotation, drying, grinding, etc. Salary, without previous experience, $5400 year to start; for experienced man, to $7800 year to start. Location, South. W7569.

Metallurgist or Mining Engineer, graduate, with one or two years experience in concentration plants or ore testing laboratories. Prefer single status. Salary, $4200 to $4500 year, plus board allowance for single man, plus $75 a month board allowance, plus housing with utilities for married man. Location, Central America. F7433.

Design-Heavy Industrial Plants: Prefer ME or MinE, to 50. Minimum of ten years experience in design of large industrial plants. Prefer detailed knowledge of metals plants, such as mills, concentrators, smelters and refineries. This includes crushing, screening, and materials handling experience. Salary range to be sufficiently high to make an attractive offer commensurate with ability. Western U.S. S(P)-4622-R.

Survey, Mapper—Mine Properties: chemical engineer or mining engineer, young. Good field survey experience in rough and rugged countries; able to translate field data into topographic and mapping of lode claims and property layouts and conduct other office work relating to lode and claim. Salary, $500 to $600. Nevada. S(P)-4603.

Mine Shift Bosses (2): Technical education preferred, but not essential. Minimum five years experience as mine shift boss, with knowledge of Spanish. Latin American experience preferable. Employed on single status, for three-year contract. Salary, $400 month, plus 2½ months salary per year. South America. S(P)-4570.

Project Planning—Building Materials Process: Ch.E, ME, MinE, EE. 30 to 38. Three to ten years experience in work related to central engineering department planning for multi-plant operations for manufacturer of building materials, roofing, paper board or paper products. Should be capable of handling planning, layouts, specifications for plant construction, expansion, modifications for increased production, improvement at pilot or operational stages. Must have potential to develop into project man, superintendent or plant engineer. Salary, $600 to $700. San Francisco East Bay. S(P)-4557-R.

Design, Application—Recording Instruments: Experienced in design, selection, and application of recording instruments and automation systems with nonferrous metal concern, including mill, mine, and smelter. Salary, $640 to $864. New Mexico. S(P)-4535.

Mine Pit Foreman, with several years experience in copper or iron deposits; capable of supervising all phases of pit development and mining, trucking and maintenance of

(Continued on facing page)

LETTERS

Hands Across the Sea

Dear Mr. Fox:

On Jan. 20, 1959, I returned safely to Tokyo from my South American trip, after the disbandment on Nov. 25, 1958, of the Applied Industrial Management Specialist Study Team of 11 Japanese professors that had been sent by Japan Productivity Center, sponsored by the U. S. Operations Mission to Japan of the International Administration, Washington, D. C.

It is a deep pleasure to me to express to you my heartfelt thanks for the warm reception you so cordially and generously extended me whilst I was in your city. Your unforgettable gracious courtesies constantly remind me of the joys of my trip, and the beauties of your country, and are for me a delight I shall ever hold in fond and grateful memory.

We left Tokyo on Oct. 14, 1958, and arrived in Seattle, Wash., on the same day, Oct. 14, by crossing the International Date Line. From Seattle we went to San Francisco and Los Angeles, Calif. Thence we went to Stillwater, Okla., where we stayed for two weeks. From there we went to Chicago, Ill., Detroit, Mich., New York, and then to Washington, D. C.

From Washington I went to Boston, Mass., accompanied by a few professors of the Team, to see the Massachusetts Institute of Technology at Cambridge, my alma mater, and the Harvard Business School there, and then returned alone to New York to prepare for the South American Trip.

Thanks to your help, I was able to spend 55 days (of the 99 days of my North and South American trip) inspecting the U. S. education and practice of industrial engineering and management, visiting various schools, factories, scenic places, old and new friends, relatives, etc. Such a pleasant trip could not have been possible without the kindness I received from dear friends like you from the time my trip was planned until its happy conclusion.

Repeating my deep thanks to you, and with happiest recollections and every good wish, I am

Yours faithfully,
Kiichi Murakami D. Eng.
Nihon University

Personnel

(Continued from page 966)

Design—Mining, Milling: graduate from accredited school, with three to five years industrial design experience. Perform duties as assigned by chief construction engineer related to design of foundations for equipment, drawing of equipment modifications and supervision of field installations, as indicated. Salary, open, to $700, depending on qualifications. For uranium mining and milling company. New Mexico. S(P)-4458.

Field Engineer—Mining Tools: mining engineer or other engineering field and two to three years experience in mining or quarrying. Visit mines and quarries and observe tests of company products (rock bits for blast hole drilling, rock cutters for drilling shafts and tunnels), discuss with mine and quarry management problems of drilling, study mechanical and metallurgical aspects of products for drilling, suggest new designs, evaluate practical and economical aspects of new projects. Short training program provided. For tool manufacturer. Travel extensively; headquarters Southwest. S(P)-4540.

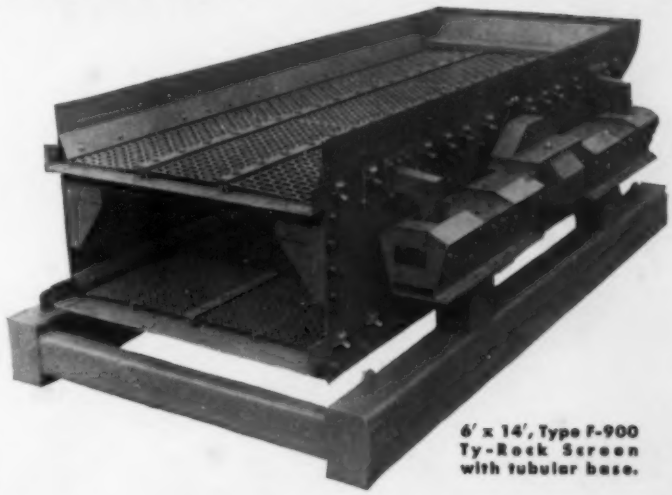
Senior Geophysicist—Mining, M.S. or equivalent, with at least eight years work with mining company to cooperate with geologists in coordinating geophysical program for exploration group of large mining company. Western U.S. Salary, open. S(P)-4453.

Designers—Underground, Open Pit Mine, mining engineer or metallurgical engineer. One for surface plant design for underground operations and also underground mine design, development and production. One for open pit design and production. Under chief engineer. Salary, commensurate with training and experience. Housing available. Wyoming. Apply by letter. S(P)-4431.

Sales Engineer—Iron Ore: graduate mining engineer or metallurgical engineer, 30 to 40, with several years practical experience plus commercial experience selling or purchasing ores and minerals. Will represent producing mines supplying iron ore to Japan steel companies. Must be married and preferably with family. Salary, open, plus free housing and business expenses. Japan. S(P)-4400.

General Pit Foreman, mining degree, 27 to 40, married or single; with five years open pit development and layout experience. Large North American mining company. Wide range of benefits. Reply in complete confidence with full particulars. Location, Peru. F7926.

TY-ROCK SCREENS



6′ x 14′, Type F-900 Ty-Rock Screen with tubular base.

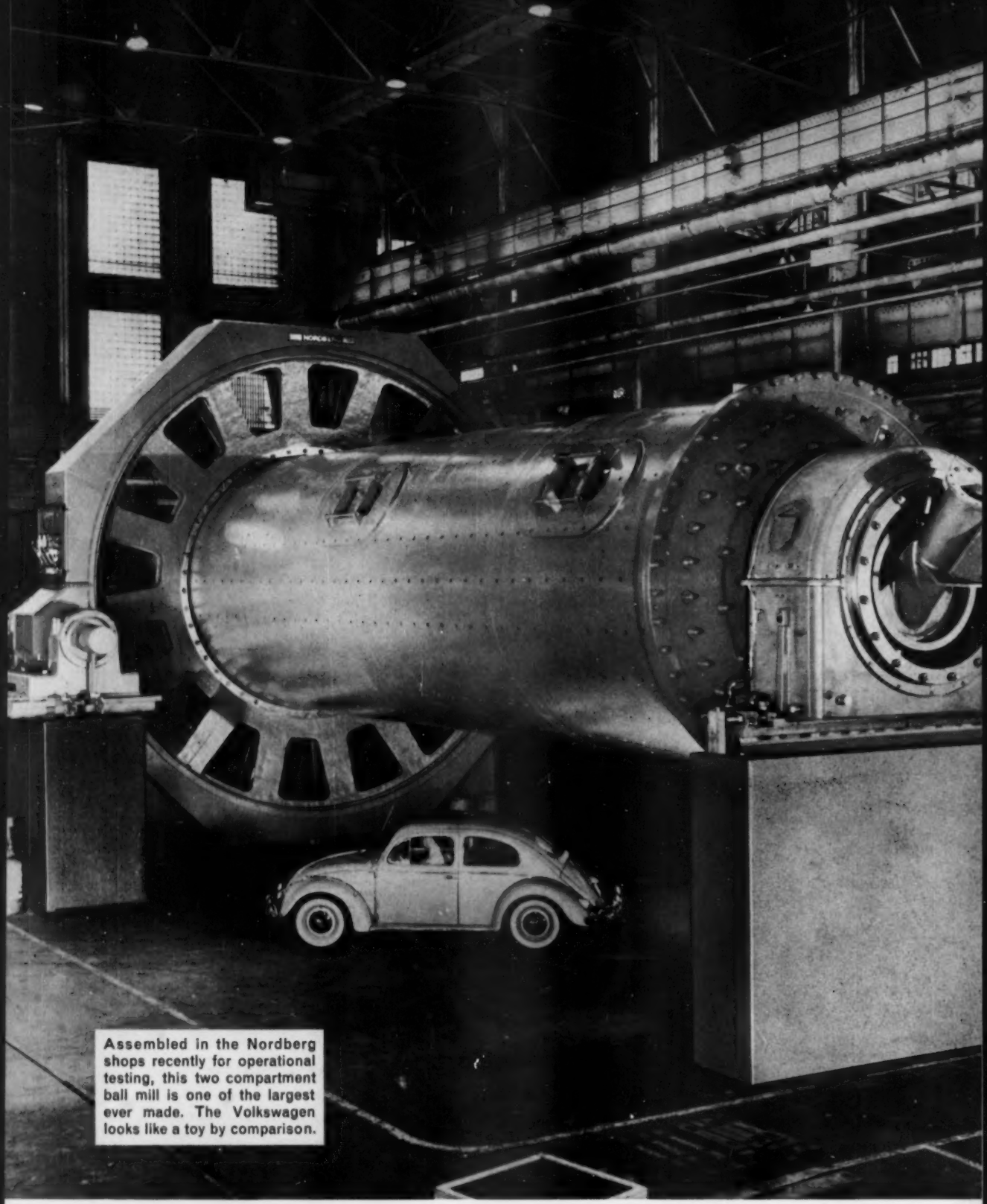
For TOP Performance

The balanced circle-throw action of the Ty-Rock plus the full-floating action on large shear type resilient rubbers enables this screen to separate material with unequalled speed and effectiveness.

The Ty-Rock wastes no power in useless, harmful racking of buildings or supporting members. It delivers all of the intense power to the job of stratifying and separating the sizes.

Telephone HE 1-5400 • *Teletype* CV 586

THE W. S. TYLER COMPANY
CLEVELAND 14, OHIO
Manufacturers of Woven Wire Screens and Screening Machinery



Assembled in the Nordberg shops recently for operational testing, this two compartment ball mill is one of the largest ever made. The Volkswagen looks like a toy by comparison.

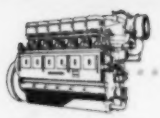
SYMONS PRIMARY GYRATORY CRUSHERS

SYMONS® CONE CRUSHERS

SYMONS VIBRATING SCREENS

SYMONS VIBRATING GRIZZLIES

ROTARY KILNS and COOLERS



NORDBERG ENGINES

NORDBERG sets the pace in LARGE GRINDING MILLS

to turn out greater tonnages at lower cost per ton

Nordberg has recently completed five of the largest grinding mills ever built for industrial service. These two compartment Nordberg ball mills (see opposite page) are 12 feet in diameter by 36 feet long, each powered by a 2500 hp synchronous motor, operating at 10% beyond rating. These mills are being installed in a new 5 million barrel per year wet process cement plant. The economies of using very large grinding mills to turn out greater tonnages at lower cost are important, however, to many other large ore and mineral reduction processes, as well.

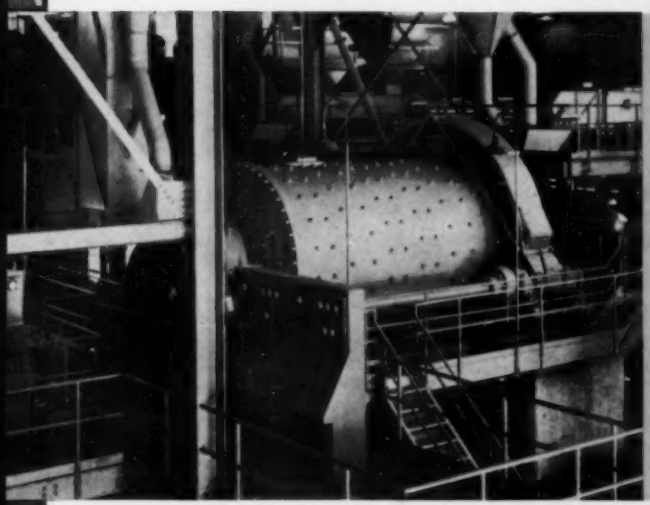
Consider some of these basic advantages:

1. *Lower construction and installation costs* . . . A single, large mill requires less floor space than several smaller ones, and only one foundation is required. Thus, construction costs are lowered and, in most cases, production is increased.

2. *Simpler automatic operation* . . . Where automatic operation is required, larger mills permit simpler handling with fewer controls. This lowers initial investment and minimizes installation and operational problems of automatic controls.

3. *Less maintenance* . . . Here, costs are again related directly to the number of mills installed. Fewer units mean less wearing parts and more dependable production. Exceptional savings may also be realized in replacement liners alone.

These are significant reasons behind the current trend toward larger grinding mills. But whether you require large or small grinding mills, you can count on the proven experience of Nordberg in furnishing the right grinding mill to meet your specific needs . . . including Rod, Ball, Pebble, Tube and Compartment types, in sizes from 6 to 13 feet in diameter and up to 50 feet in length. *Write for further information.*



Shown here are two of five 11′ x 17′ Nordberg Ball Mills—three raw and two finish—installed in a midwest cement plant that has a capacity of 3,000,000 bbl. annually.

The largest iron ore mill installation in the world with 58 Nordberg Grinding Mills. This concentrator building houses 27, 10′ x 14′ rod mills and 27, 10′ x 14′ ball mills. Four Nordberg mills serve as standby units.

NORDBERG MANUFACTURING COMPANY, Milwaukee 1, Wis.

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NORDBERG

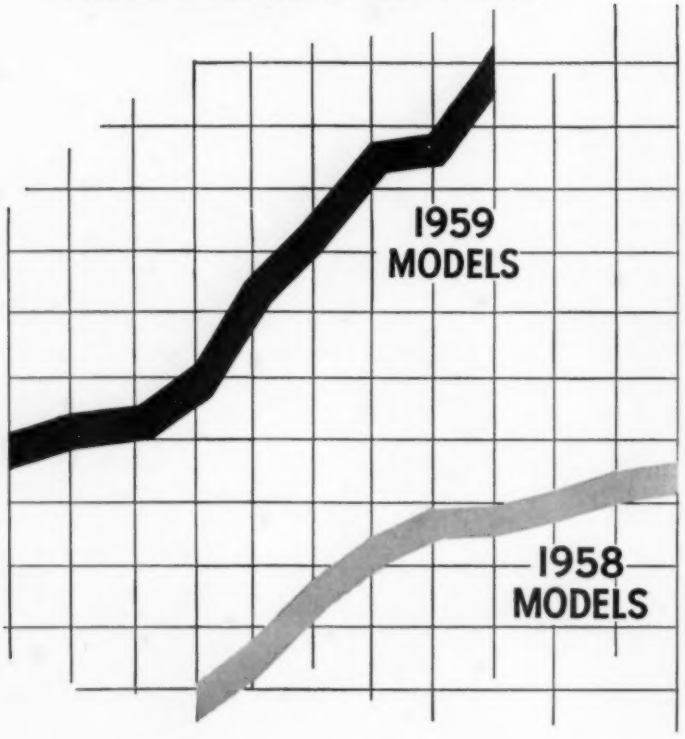
SYMONS . . . a registered Nordberg trademark known throughout the world.

SYMONS SCREENS NORDBERG

ATLANTA ◦ CLEVELAND ◦ DALLAS ◦ DULUTH ◦ HOUSTON ◦ KANSAS CITY ◦ MINNEAPOLIS ◦ NEW ORLEANS ◦ NEW YORK ◦ ST. LOUIS
SAN FRANCISCO ◦ TAMPA ◦ WASHINGTON ◦ TORONTO ◦ VANCOUVER ◦ JOHANNESBURG ◦ LONDON ◦ MEXICO, D. F.

The BIG SUCCESS

1959 FORD SUPER DUTY TRUCK SALES MORE THAN DOUBLE THOSE OF LAST YEAR



1960 FORD SUPER DUTIES

SKYROCKETING SALES OFFER ADDED TESTIMONY TO THE TOUGHNESS AND RELIABILITY OF FORD "BIG V'S"— *NOW THEY'RE MORE DURABLE, MORE FLEXIBLE THAN EVER!*

Ford's increase in sales of Super Duty Trucks, while impressive in itself, by no means tells the whole story. Over half of the 1959 unit sales were the result of repeat orders from operators like Trucking Contractors, Inc., who bought because the Ford "Big V" provided the kind of performance and durability needed for their work.

And for 1960, the Ford Super Duties offer additional refinements designed to provide an even greater degree of dependability. Bigger optional axles and increased GVW's permit greater payloads and more profitable operation. Automatic radiator shutters to keep the engine temperatures within the most efficient operating range, submerged-type electric fuel pump to prevent vapor lock, and redesigned wiring for longer, more dependable operation are but a few of the improvements which add to the performance and durability of these units.

The changes offered for 1960 were tested and evaluated by America's foremost independent automotive research organization. The certified results of the studies by this impartial firm (name available on request) provide proof that Ford's Super Duty Trucks are even more dependable.

- **Certified Durability through closer temperature control!** Independent research engineers certify that Ford's thermostatically controlled radiator shutters kept water temperature between 168° and 188° in severe mountain grade operation. The test truck with shutters blocked open

of the Big Truck Field

"Tried 8 in '58—bought 20 more in 1959," says Curtis E. Brost, President, Trucking Contractors, Inc. "In 1958 we bought 8 Ford T-850's with lightweight chassis options and specially built 5-batch bodies which gave us a full extra batch per truck. A 5-batch load is a real strain on the truck when you consider we're 'running the ditches' on this highway paving job in North Dakota. These T-850's worked out so well that we ordered 20 more in '59. Our Ford Tandems with the 477 engine give us good mileage and the drivers are real happy with them. It's a rough go on trucks with soft footing and dust so bad we have to drive with headlights on. Despite such operating conditions, downtime has been negligible and these '477' Fords have given us less trouble than other trucks we have operated."

with Certified Durability

under same operating conditions had a temperature range from 102° to 181°. The temperature variation of only 20° with shutters means less expansion and contraction in engine block and cylinder heads. Higher temperatures with radiator shutters permit leaner fuel-air mixtures with less possibility of raw gas washing down cylinder walls. Warm oil circulates more freely, reducing internal friction. All these factors contribute to longer engine life.

- **Certified Dependability with longer-lived electrical system!** Ford's '60 improved wiring harness and the 1959 wiring harness were subjected to shaker table tests plus constant exposure to oil and water vapors and temperatures of 200°. Certified results prove that the greater resistance to deterioration by heat, oil, water and abrasion obtained with the 1960 wiring harness more than doubles wiring harness life.

- **Certified Reliability with Ford's submerged-type electric fuel pump!** Dynamometer tests of engines with submerged-type electric fuel pump and conventional mechanical type showed that vapor lock was non-existent with Ford's electric pumps at temperatures up to 200°, whereas incipient vapor lock with mechanical pump resulted in a power loss of 9% at an underhood temperature of 200°.

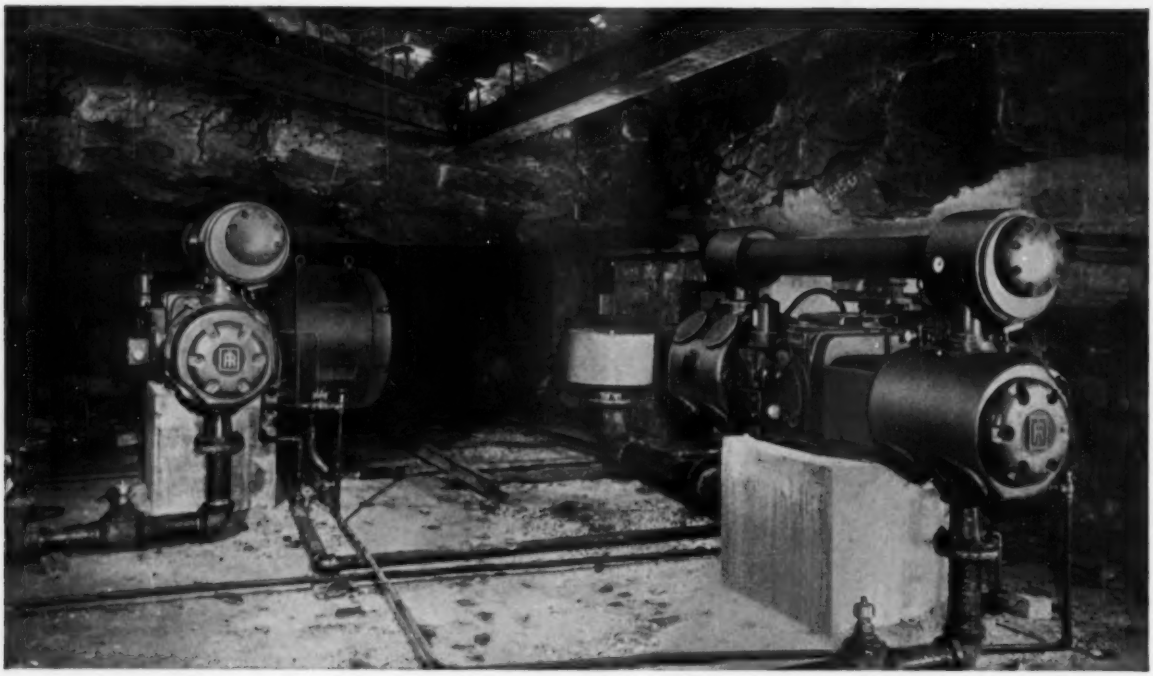
Test results like these plus the experience of satisfied users are important but that is not all. For 1960, the Super Duty line has been broadened to provide even more flexibility in power train options. Get the facts from your Ford Dealer!

FORD TRUCKS COST LESS

LESS TO OWN . . . LESS TO RUN . . . BUILT TO LAST LONGER, TOO!

CRAMPED FOR SPACE?

PHE compressors need less headroom, can be skidded in fully assembled

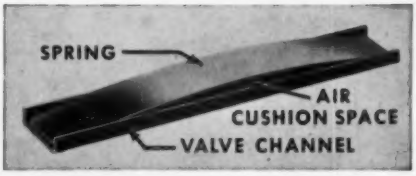


Squeezing a heavy-duty compressor through narrow drifts and installing it in a tight place is an old mining problem. The solution may be an Ingersoll-Rand PHE compressor... as was the case in the mine picture above.

These packaged units are ideal for mine service – they can be skidded through tight places completely assembled and installed on a simple block foundation.

The PHE is a two-stage intercooled compressor with balanced-opposed cylinder construction in 75 and 100-hp sizes, built for continuous full-load operation. Bearing wear and overall maintenance costs are minimized, due to (1) long-life aluminum full-floating bearings, (2) filtered force-feed lubrication, and (3) a completely sealed crankcase that never needs to be opened for any adjustments.

PHE compressors feature the Channel Valve, renowned for its remarkable durability, long life, and freedom from maintenance. Each valve is a



combination of straight-lifting, stainless-steel valve channels and leaf springs, which form trapped air spaces to cushion the opening action. This exclusive air-cushioned design prevents impact, reduces wear, and assures quiet, efficient operation. And remember, *only I-R compressors have Channel Valves!*

For further information on compressors, rock drills, and other equipment for mining services, contact your Ingersoll-Rand representative.

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Mineral Information

An International Directory of Engineering Source Material

BOOKS

Order directly from the publisher all books listed below except those marked • • • The books so marked (• • •) can be purchased through AIME, usually at a discount. Address Irene K. Sharp, AIME Book Dept., 29 W. 39 St., New York 18, N. Y.

Ground Water Hydrology, by David Keith Todd, *John Wiley & Sons, Inc.,* 348 pp., $10.75, 1959—This book meets the present demand for a unified, comprehensive account of the fundamentals and recent methods in the ground water hydrology field. Problems such as locating a ground water supply, constructing a well, determining how much water it will yield, control of sea water, and dangers of pollution are covered. • • •

Analysis of Industrial Operations, edited by Edward H. Bowman and Robert B. Fetter, *Richard D. Irwin Inc.,* Homewood, Ill., 494 pp., $9.55, 1959—A unique collection of case studies showing actual application of quantitative methods for the analysis of industrial operating problems. The articles included provide insight into the simplifications, assumptions, methods modifications, etc. • • •

Careers and Opportunities in Engineering, by Philip Pollack, *E. P. Dutton & Co., Inc.,* 300 Fourth Ave., New York 10, N. Y., 158 pp., $3.50, 1959—A comprehensive account of the engineering profession including career opportunities in civil, mechanical, electrical, chemical, mining, metallurgical, and petroleum fields. Qualifications, personal traits and abilities needed for success in various aspects are discussed. • • •

Air Pollution Control, by W. L. Faith, *John Wiley & Sons Inc.,* 259 pp., $8.50, 1959—Basic factors in any air pollution control program begin with an explanation of the effects of air pollution and the importance of meteorological variables. Details of methods that determine amounts of contaminants in the air and their elimination at the source are considered. • • •

Methods and Case Histories in Mining Geophysics, arranged by a committee of geophysicists of the Canadian Inst. of Mining and Metallurgy, published by *6th Commonwealth Mining and Metallurgical Congress,* 911 Drummond Bldg., Montreal, P. Q., Canada, 368 pp., $10, 1959—This comprehensive volume is devoted to recording a series of case histories dealing with geophysical methods in mining exploration and other subsurface investigations. Magnetic, gravitational, geochemical, radioactive, electrical, and seismic methods are covered in papers by experts in each field. Specific case histories in Australia, Canada, Great Britain, India, Jamaica, South Africa, Tanganyika, and Uganda are described. Numerous detailed drawings, charts, and diagrams carefully delineate the case histories, and a special pocket includes several useful maps. • • •

Engineering and Organization, by Everett Laitala, *Richard D. Irwin Inc.,* Homewood, Ill., 391 pp., $7.20—The goals of engineering are defined and the standards by which its performance can be evaluated are established. The greatest portion of the book is concerned with the place of the engineering process within the over-all structure of an industrial enterprise. Management, product specification, budget, design, production, selling, buying, maintenance, personnel are covered. • • •

The Structure of Electrolytic Solutions, edited by Walter J. Hamer, *John Wiley and Sons Inc.,* 441 pp., $18.50, 1959—A wide range of topics relating to the properties of electrolytic solutions are covered, extending from dilute solutions through concentrated solutions and fused electrolytes as well as the pure ionic solid state. • • •

Year Book of the American Bureau of Metal Statistics, 1958, Thirty-eighth annual issue, compiled and published by the *American Bureau of Metal Statistics,* 50 Broadway, N. Y., paper $4, hard cloth, $4.50, 1959—This enlarged edition records for 1958 and prior years the mine production, smelter production, consumption, imports and exports, and other economic statistics on a world-wide basis. • • •

Engineers Societies Directory, 1959, *Engineers Joint Council,* 29 West 39th Street, N. Y. 18, N.Y., $3.50, 1959—This directory is the only comprehensive U. S. listing of engineering and scientific societies, their functional staff personnel, and publications. • • •

Rare Earth Handbook, *Battelle Memorial Inst.,* 505 King Ave., Columbus 1. Ohio, 214 pp., $10, 1959—The Rare Earth Research Group has released this handbook of information contained in recent technical papers. It brings together for the first time the most recently available data on the physical, crystal, chemical, electrical, magnetic, nuclear, and thermodynamic properties of each of the 15 metals. • • •

Compendium of Water Pollution Laws, *Manufacturing Chemists' Assn. Inc.,* 1825 Connecticut Ave., N. W., Washington 9, D.C., Manual W-5, $5, 1959—Federal and state laws are covered chapter by chapter by Carl E. Geuther of the Legal Dept., E. I. du Pont de Nemours & Co. Inc.

American Standard Illustrations for Publications and Projection, Y15.1-1959, *The American Society of Mechanical Engineers,* 29 W. 39th St., New York 18, N. Y., 16 pp., $2, 1959—A new guide to help authors prepare clear and legible illustrations for technical papers has been approved by the American Standards Assn. and published by the ASME. Standard methods of preparing graphs, line drawings, and tabular illustrations are described with an emphasis on simplicity and unity.

Correction

The correct price of the volume **Axial Flow Compressors** by J. H. Horlock, *Butterworth & Co. Ltd.,* 1367 Danforth Ave., Toronto, 6, Ont., Canada, is $8.00, instead of $5 as listed in the September issue, page 858. To order the publications **The Geology of the Odzi Gold Belt,** Bulletin 45, approx. $2.15 (12s) and **Mineral Map of Southern Rhodesia,** 15¢ (1s.) send to P. O. Box 8039, Causeway, Salisbury, Southern Rhodesia, instead of Swaziland as incorrectly listed in the August issue, page 764.

(*Continued on page 974*)

BOOKS

Continued from page 973

STATE PUBLICATIONS

Arizona

Arizona Bureau of Mines
University of Arizona
Tucson, Ariz.

Geologic Map of Final County, Ariz., 75¢.

California

Gold Rush Country, *Lane Publishing Co.*, Menlo Park, Calif., $1.75, 1957.
Mineral Production in the Territory of Hawaii, Area Report II-20, available from Bureau of Mines, Div. of Mineral Industries, Region II, 420 Custom House, 555 Battery St., San Francisco 11, Calif.

Illinois

State Geological Survey
Natural Resources Bldg.
Urbana, Ill.

Crevice Lead-Zinc Deposits of Northwestern Illinois, Report of Investigations 210, 25¢.
Barite in the Southern Illinois Fluorspar District, Circular 265, 3¢ postage.
Water-Sorption Characteristics of Clay Minerals, Circular 266, 4½¢ postage.
Spar Mountain Sandstone in Cooks Mills Area, Coles and Douglas Counties, Circular 267, 4½¢ postage.
Effect of Coal Inventories on Stability of the Coal Industry, Circular 268, 3¢ postage.
Plastic Properties of Coal, Circular 269, gratis except for postage.
Subsurface Geology and Coal Resources of the Pennsylvanian System in Douglas, Coles, and Cumberland Counties, Illinois, Circular 271, gratis except for postage.

Indiana

Publications Section
Geological Survey
Indiana University,
Bloomington, Ind.

Natural Brines of Indiana and adjoining parts of Illinois and Kentucky, Report of Progress No. 13, 85¢.
Cement Raw Materials in Indiana, Bulletin No. 15, $2.20.

Kansas

State Geological Survey
University of Kansas
Lawrence, Kan.

Description of a Dakota (Cretaceous) Core From Cheyenne County, Kansas, Bulletin 134, Part 1, 25¢.
Cement Raw Materials, Bulletin 134, Part 2, 25¢.
Sandstones of the Douglas and Pedee Groups in Northeastern Kansas, Bulletin 134, Part 3, 25¢.
Germanium in Kansas Coals, Bulletin 134, Part 4, 25¢.
Coal Resources of the Cherokee Group in Eastern Kansas, Bulletin 134, Part 5, 25¢.
Symposium on Geophysics in Kansas, Bulletin 137, $2, 1959.

Kentucky

Kentucky Geological Survey
Mineral Industries Bldg.
120 Graham Ave.
Lexington, Ky.

Mineral Resources Summary for Kentucky 1955 and 1956, Report of Investigation 14, $1, 1958.
Sources of Shale in Kentucky for Lightweight Aggregate Production No. 2, Report of Investigation 15, 50¢, 1958.
High-silica Sandstone and Conglomerate on Pine Mountain near Elkhorn City, Kentucky, Series X 1, 25¢, 1959.
Geology and Mineral Resources of the Prestonburg Quadrangle, Kentucky, Bulletin 22, $2, 1958.
The Mineral Industry of Kentucky (1957), Series X 1, 25¢, reprint 1959.
Coal Geology of the White Oak Quadrangle, Magoffin and Morgan Counties, Kentucky, $1.25.
Geology and Coal Resources of the Tiptop Quadrangle, Kentucky, $1.25.

Maine

Maine Geological Survey
Dept. of Economic Development
State Office Bldg.
Augusta, Maine

Geology of the Beck Pond Area, Township 3, Range 5, Somerset County, Maine, Special Geologic Studies Series No. 1, 75¢.
Glacial Lake and Glacial Marine Clays of the Farmington Area, Maine, Special Geologic Studies Series No. 3, 75¢.
Mineral Resources of Maine, Reference Map Series, Portland-Bath Sheet, 25¢.
The Geology of a Six-Mile Section Along Spencer Stream Somerset County, Maine, Special Geologic Studies Series No. 2, 70¢.
The Maine Mining Law for State-Owned Lands, 35¢.

Missouri

Missouri Geological Survey
P. O. Box 250
Rolla, Mo.

Sixth Biennial Report of the Division of Geological Survey and Water Resources to the Seventieth General Assembly, 10¢.
Guidebook, Field Trip, 1958 Annual Meeting of the Geological Society of America, Report of Investigations No. 25, 50¢.
Bibliography of the Geology of Missouri, 10¢, 1958.

Montana

Bureau of Mines & Geology
Montana School of Mines
Butte, Mont.

Summary of Montana Mineral Resources, gratis, revised 1959.
Geologic Map of the Northwest Flank of the Flint Creek Range, Granite County, Montana, Special Publication 18, 40¢, 1959.
Geology of the South Moccasin Mountains, Fergus County, Montana, Memoir 37, $1.
Geology of the Cherry Creek Area, Gravelly Range, on open file at the Montana School of Mines Library.

Nevada

Nevada Bureau of Mines
University of Nevada
Reno, Nev.

Geology of the Candelaria Mining District, Mineral County, Nev., Bulletin 56, $2.15, 1959.

New Mexico

State Bureau of Mines and Mineral Resources
Campus Station,
Socorro, N.M.

Some Ordovician Corals From New Mexico, Arizona and Texas, Bulletin 64, 50¢.
Metallogenic Provinces of the Southwestern United States and Northern Mexico, Bulletin 65, $2.50.

North Dakota

State Geologist
University Station
Grand Forks, N.D.

Clays of North Dakota as a Potential Source of Alumina. Report of Investigations No. 33, 50¢, 1959.

U. S. BUREAU OF MINES

Copies sold through:

Superintendent of Documents
Government Printing Office
Washington 25, D. C.

RI 5436 Some Thermodynamic Properties of Fluorpheogopite Mica, 20¢, 1959.
IC 7860 A Reconnaissance of Asbestos Deposits in the Serpentine Belt of Northern California, 60¢, 1959.
IC 7882 Selected Bibliography on Low-Temperature Tar, 35¢, 1959.

Request free publications from:

Publications Distribution Section
U. S. Bureau of Mines
4800 Forbes Ave.
Pittsburgh 13, Pa.

RI 5475 Preparation Characteristics of Coal From Washington County, Pa.
IC 7878 Tin-Pacer Sampling Methods and Results, Cape Mountain District, Seward Peninsula, Alaska.
IC 7879 Sinking Methods and Costs at the Burgin Shaft, Bear Creek Mining Co., East Tintic Project, Utah County, Utah
IC 7885 Respiratory Protective Devices Approved by the Bureau of Mines as of October 16, 1958.
IC 7888 Mining Methods and Costs at the Anaconda Co. Berkeley Pit, Butte, Mont.
IC 7889 Airflow Changes in Multiple-Fan Systems.
IC 7890 Block-Caving Mining Methods and Costs, Bagdad Mine, Bagdad Copper Corp., Yavapai County, Ariz.
IC 7891 Methods and Costs of Mining Lignite in North Dakota.
IC 7892 Analysis of 494 Accidents, Open-Pit Iron Ore Mines, Beneficiation Plants, and Shops, Lake Superior District.
IC 7893 Review and Status of Low-Temperature Tar Investigations of the Bureau of Mines.

ABSTRACTS

In This Issue: *The following abstracts of papers in this issue are reproduced for the convenience of members who wish to maintain a reference card file and for the use of librarians and abstracting services. At the end of each abstract is given the proper permanent reference to the paper for bibliography purposes.*

Replacement of Capital Equipment, by *Henry J. Schwellenbach*—Lack of a system in scheduling the replacement of capital equipment can result in emergency purchases of units which may later be found unsuitable. New York Trap Rock Corp. conducted an evaluation of several systems for efficient replacement. The paper reviews the findings of the company that led to their individualized plan for cutting costs. **Ref. MINING ENGINEERING, October 1959, p. 1003.**

Copper, Lead, And Zinc—Predictions and Experience by *Evan Just*—Further analysis of the forecasts made by the President's Material Policy Commission in 1952 shows where the committee overrated U. S. consumption and underrated consumption elsewhere in the Free World. Nevertheless it is too early to tell, since only a third of the projected time has elapsed, how accurate the Paley report figures were, especially since some of the figures themselves were estimates and have been corrected. A table of copper, lead, and zinc consumption gives some basis for comparison. **Ref.: MINING ENGINEERING, October 1959, p. 1006.**

Stockpiling: Purposes, Methods, Tools, by *L. O. Millard*—Stockpiling is important to all segments of our economy, but it is a term that means many things to many people. To men in industry it means piles for reserve supply over winter, or insurance against strikes and shipping delays, or use as surge at various production stages, or inventory of finished products. Important factors affecting the methods and tools of stockpiling are covered in the paper, including the following: the material to be stored; the quantity required; length of storage time; rate of turnover; rates at which material is stored and reclaimed; and climate and weather influences. **Ref.: MINING ENGINEERING, October 1959, p. 1008.**

Self-Fluxing Sinter by *T. E. Ban, C. D. Thompson, and C. A. Czako*—Continuous sintering has broadened from its origin in nonferrous metallurgy to present-day applications in the ferrous, chemical, and nonmetallic fields. The recent accomplishments in Europe can be interpreted only with an understanding of European raw materials and economics. European research work involved additions of small percentages of lime to iron ore agglomerates, with attendant benefits to sinter capacity and sinter strength. Technical data on such improvements are included in the paper. **Ref.: MINING ENGINEERING, October 1959, p. 1015.**

The Shear Strength of Rocks by *Rudolph G. Wuerker*—Recently available results of measurements of the tensile and comprehensive strength of rocks permit determination of shear strength by a simple graphical method. While most previous measurements of shear strength have been made by time-consuming and expensive triaxial tests, the U. S. Bureau of Reclamation has shown that the drawing of a straight line tangent from the tension circle to the compression circle in a Mohr's diagram can be used as a useful approximation. Evaluated were 26 rocks and one sample of concrete. Shear strength and straight-line equation of Mohr's envelope of these rocks are computed and tabulated. While this procedure is to be used with some precaution when determining properties of a specific rock, it is of great importance when discussing the behavior of rocks in general and when trying to find a unified theory for the failure of brittle materials. Shear strength is not stated as an independent property. Its

dependence upon compressive and tensile strength is shown graphically, based upon an expansion of Mohr's theory. The influence of confinement on the results of common tests and on behavior of rock in drilling and blasting is investigated. Parameters are established for shear strength and for the slope of Mohr's envelope. **Ref.: MINING ENGINEERING, October 1959, p. 1022.**

Deflection of Mine Roof Supports by *Lawrence Adler* (TP 4816A)—When a mine roof is designed for maximum safe span, it is usually assumed that the differential deflection of the supports is zero. However, should an apparently insignificant deflection exist, stresses in the roof can quickly exceed the allowables. Consequently, where these deflections are indeterminate, strong measures should be taken to minimize them and if possible to make them zero. When a mine roof is designed for some convenient lesser span, controlled, permissive deflection will result in lower loads on the props or bolts. A corollary action increases the load on the other support. If this is the rib, conditions favorable to longwall caving can then be induced in the working face. **Ref.: (MINING 214, p. 1027.**

ENGINEERING 1959) AIME Trans., 1959, vol. Relation of Land Subsidence to Ground-Water Withdrawals in the Upper Gulf Coast Region, Texas, by *A. G. Winslow and L. A. Wood* (TP 59H2)—Subsidence of the land surface has occurred in several areas of the upper Gulf Coast region of Texas and in most of these sectors appears related to removal of ground water. In the principal area, the vicinity of Houston and Galveston, heavy withdrawal of ground water for a series of unconsolidated sands interbedded with clays has caused regional land-surface subsidence. Most of the subsidence is attributed to compaction of clays and other fine-grained materials as the artesian pressure head is lowered in the water-producing sands. Rate of subsidence has been about 1 ft for each 100 ft of decline of pressure head, and recent releveling has shown no appreciable change in this rate. Subsidence in this region probably will continue indefinitely even if groundwater withdrawals are not increased, because the head in shallow sands will continue to decline as it adjusts to lower heads in the deeper sands. **Ref.: (MINING ENGINEERING, October 1959) AIME Trans., 1959, vol. 214, p. 1030.**

The Electronic Computer and Statistics for Predicting Ore Recovery by *Robert F. Shurtz* (TP 4817I)—When an ore deposit is evaluated on the basis of core sampling, questions always arise as to how much weight should be given the various sample grades and how the deposit should be divided into specific volumes assigned to corresponding grades. The author proposes a method used with some success on a magnesite deposit at Gabbs, Nev. He believes this procedure to be more sound than the blind practice of assigning uniform quality to large, sometimes vast blocks of ore on the basis of analyses made of a small number of samples. **Ref.: MINING ENGINEERING, October 1959) AIME Trans., 1959, vol. 214, p. 1035.**

Fishing Tools for Retrieving Gamma-Ray Logging Components by *C. M. Bunker and J. M. Ohm* (TN 591211)—The authors have designated and constructed special tools for recovering gamma-ray probes and logging cable for drillholes. Though intended specifically for U. S. Geological Survey equipment, they may be used with other equipment of the same general type. **Ref.: (MINING ENGINEERING, October 1959) AIME Trans., 1959, vol. 214, p. 1045.**

SME Meeting Papers: *The following abstracts of papers presented at SME meetings are given for your information. Copies of these papers are available* **only if followed by a preprint order number.** *These preprints are obtained on a coupon basis. The coupon books may be purchased from SME headquarters for $5.00 a book (10 coupons) for members of AIME or $10.00 a book for nonmembers. Each coupon, properly filled out, entitles the purchaser to one preprint. Mail completed coupons to Preprints, Society of Mining Engineers, 29 W. 39th St., New York 18, N. Y.*

A Long Range Appraisal of Mechanized Mining by *A. Lee Barrett*—Two general trends will be noticed in a comparison of the present with mechanized mining 10-20 years hence. a) The inherent advantages of specialized coal mining machinery will be integrated into a mining plan most suited to the machinery. This will provide a reduction of real cost by reducing the size of the mine, thereby reducing such specific costs as ventilation, drainage, supervision and mine maintenance. Such an integrated mining plan will make possible specific improvements in other portions of the mining equipment in other than face mining equipment, particularly in such fields as transportation. b) There will be further improvement in face mining machinery. Machinery will be developed providing a higher output per man shift, lower maintenance cost and higher overall safety values for the operating personnel. Machinery will also be available for lower seam operations. *AIME-ASME Joint Solid Fuels Conference, Cincinnati, October 1959.*

Design of a Modern Coal Mine by *George W. McCaa*—This paper covers the design of the Ireland mine of the Hanna Coal Co. Div. of Consolidated Coal Co. This is a new mine that was built to supply fuel for an electric utility plant. Economy and efficiency were considered in all phases of the mine design. The paper includes the plans and construction of the surface and underground facilities; seam and roof conditions; utilization of A. C. power at the face; continuous mining and roof bolting; underground rail haulage with large mine cars; and an efficient closed circuit cleaning plant to wash plus ¼ in. coal. *AIME-ASME Joint Solid Fuels Conference, Cincinnati, October 1959.*

Special Railroad Rates for the Movement of Coal in Volume Quantities by *C. P. Blair*—This paper will deal with the various types of special rates for the movement of coal in volume quantities. In recent months the railroads have established various types of rates which are frequently referred to as trainload, volume, or multiple car (daily, weekly, or annual) and conditional or increment rates, in an effort to enable coal to compete with other fuels. The advantages and disadvantages of each type as well as the operating and traffic problems with which the railroads are confronted will be covered. It will be explained that the carriers are not committed to any type of volume requirements but have endeavored to fix the measure of the rates and the volume requirements on the competitive situations existing in connection with each individual situation. *AIME-ASME Joint Solid Fuels Conference, Cincinnati, October 1959.*

Preparation of Coal For Electric Utility Use by *Myron W. Mellor*—Paper will deal with the methods employed to make coal a superior fuel for electric power generation. Preparation will be viewed from an economic standpoint in an effort to determine justification for costs. Also, comparisons will be presented between use of coal for power generation and other uses to emphasize its relative importance and consequent need for careful consideration of preparation methods. *AIME-ASME Joint Solid Fuels Conference, Cincinnati, October 1959.*

The Preparation of Coal for Industrial Consumption by *Arthur S. Maynard*—The preparation of coal for the industrial market presents several important factors that would be of lesser importance in the preparation of coal for other markets. Due to the various types of equipment and the varying loads on equipment in industrial plants, coal supplied to these plants must vary in top size, pct fines, ash, and moisture. A preparation plant supplying the coal would have to meet specifications such as crush plus 2 in. coal to minus 2 in. coal. The range of ash for industrial coal may be greater than for coals supplied to other markets. From the standpoint of handling, freight costs, and reduction of BTU the reduction of moisture is important to the industrial user. Some method of thermal drying is necessary. *AIME-ASME Joint Solid Fuels Conference, Cincinnati, October 1959.*

Control—The Key to Preparation for the Export Market by *M. P. Corriveau*—As the purchaser's requirement for quality coals becomes more precisely defined, the coal producer must go to more elaborate analytical facilities in order to meet the growing competition in the export market. The paper presents what the Clinchfield Coal Co. has done to satisfy its need for better control of the quality of its coal for this, as well as the domestic, market. *AIME-ASME Joint Solid Fuels Conference, Cincinnati, October 1959.*

Operating Controls at the Climax Molybdenum Mill, Climax, Colorado by *Frank J. Windolph*—Increased costs of labor and material, combined with the downward trend in the grade of ores mined, has made increased efficiency not just desirable but necessary in the mineral industry. Climax Molybdenum Company, in an aggressive program to apply instrumentation and automatic process controls to its operations, has found that these tools make a significant contribution to overall efficiency. Two recent applications of controls to unit operations—classified sand load and cone crusher load controls—are described. *AIME Colorado Section MBD Meeting, May 1959.*

Operating Controls in Ore Dressing Plants by *John Barnes*—Defining controls as those things which the mill operator should know about the condition of his mill in order to guide him in making the adjustments necessary for efficient operation, the author describes devices and methods observed in operation; ore feed, grinding circuit, pump surging or pump sump levels, leaching operations, thickener operations, and iron-exchange in solvent-extraction processes. In addition, general controls in use in uranium processing are described. Certain general observations and conclusions on the subject of controls are made and ideas for improvements such as a practical continuous viscosimeter are given. *AIME Colorado Section MBD Meeting, May 1959.*

The Mill With No Operators by *Wayne Hazen and S. Power Warren*—A discussion on ore beneficiation plant design and operation led to the question "How could you build an ore treatment plant that would run itself—no operators?" Considerable description is given of such a hypothetical plant in operation in the year 1969. Justification is given for many of the parts of the operation, since the ideas have their inception and basis in the unprecedented advance in scientific instrumentation, especially in chemical engineering. New ore beneficiation equipment must be designed without regard to the old for it should be kept in mind that such equipment in the past has been designed to be operated by a human being. Instrumentation and ore automatic controls, installed to replace operators in a plant, require additional trained technical personnel and do not prove economical. Increasing automation will be reflected in employee education. *AIME Colorado Section MBD Meeting, May 1959.*

Preventative Maintenance — Concentrating Plants and Chemical Plants by *R. W. Unger*—Preventative maintenance is a program designed and executed as a major factor in economic plant operation. Most wear is visible and maintenance can be generated on a control basis in concentrating plants employing dry crushing where the plants are operated in conjunction with a mining operation. A judicial cleaning program combined with preventive maintenance fatigue, based upon experience, does much to eliminate the shock of emergency repair. Adjustment and maintenance are even more critical in those uranium processing units which are not mine attached. Usually such plants are more complex in structure and operation and a planned maintenance program is essential. The entire field of preventative maintenance, since it is an important ecomonic factor in operations, must be closely tied to the philosophy of management and already existing plants. *AIME Colorado Section MBD Meeting, May 1959.*

A Guide to the Use of Protective Coatings by *Robert F. Jones*—A general guide is provided for the use of protective coatings as one tool of several that can be used to decrease materially the annual corrosion rate in a particular plant or mill. Since this is a practical, rather than technical, approach to the problem, the following aspects are covered: 1) capital investment loss through corrosion as compared with cost of maintenance, 2) selection of coating system, 3) coating failures that are minimized by preferred design of the structure to be protected, 4) surface preparation against rust, mill scale, oil, grease, dirt, etc., 5) the necessity for tight specifications, 6) coating application, and 7) systematic inspection after coating. The economic approach to the problem of metallic corrosion offers a logical and sound basis of decision for the adoption of a coating program. When considered in this light, adoption of such procedures removes coating programs from the status of "necessary evils". *AIME Colorado Section MBD Meeting, May 1959.*

Preventative Maintenance Practice at the Eagle Mine, Empire Zinc Division, The New Jersey Zinc Company, Gilman, Colorado by *H. Steinmier and F. J. Witthauer*—Preventative maintenance as performed at Gilman is the result of years of experience and takes advantage of the weekend down time available when operations are geared to a five day week. Details are given of the program supervision and planning which are the jobs of the mine and plant chiefs. Lubrication which is a prime factor in the program is scheduled by the plant department following manufacturer's recommendations, recommendations of the lubricant supplier, and results of Gilman experience. The preventative maintenance program consist of two main classifi-

(Continued on page 978)

New power! New design! New features! Plus a new drive option—Cat power shift transmission! The result: higher production on any application!

Now the "King of the Crawlers" is better than ever with new pace-setting capacity for higher, faster, lower-cost production on *any* big tractor application!

The biggest "new look" in the giant D9 Series E is the undercarriage. It's more massive . . . more rugged than ever. It'll add hours of life to running gear on even the toughest jobs. *Every* track component is new in design, highlighted by a big, new link—its pitch is increased 1¼" to 10¼"! And a new Caterpillar-developed steel alloy strengthens links, shoes, rollers *up to 40%!*

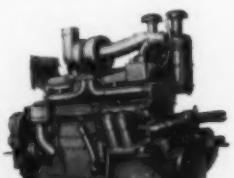
That's not all: the new D9 packs more power—335 HP. Its new equalizer bar gives greater stability on any terrain for greater operator confidence and production. A wider seat with a new spring-loaded adjustment mechanism makes the operator more comfortable, more efficient. No detail has been overlooked to make the new D9 handle heavier loads faster—and at lower operating and maintenance costs than ever.

And that's not all. Now, along with direct drive and torque converter, you have your choice of the new Cat

Dry-type air cleaner. Removes at least 99.8% of all dirt from intake air during every service hour. Can be serviced in 5 minutes. Reduces maintenance time and cost.

Exclusive feature. A planetary gear set splits the power from the engine. Part goes directly to the 3-speed transmission, the rest goes through a torque converter to transmission.

New sprocket. Sprocket is strengthened by new design with increased tooth thickness. Hunting tooth action provides slower wear rate.



New 335 HP. More powerful than ever, the D9's Turbocharged Engine has the capacity to handle bigger loads faster, with dependability, economy.

New Turbocharger. New, compact turbocharger packs more air into the engine. Open impeller wheel (shown below) helps prevent dirt build-up.

New power shift transmission. Optional on the D9. With this development you can shift **on-the-go** under full load with one lever and no clutching in a split second!

New, bigger, more rugged undercarriage. Major improvements in all track components add hundreds of hours of life to running gear—hours that mean more time on the job.

New equalizer bar. Greater stability. The rocking action of the bar shifts more weight to the up-hill track.

new CAT D9 E Tractor

power shift transmission. This revolutionary transmission, tested under the most rugged conditions, combines for the *first* time the positive feel of direct drive with the flexibility and anti-stall features of torque converter. With one control lever and no clutching, it reverses direction . . . changes speed . . . smoothly . . . under full load . . . in a split second!

Many of the new features, along with some familiar retained features, are shown here. Look them over. They'll give you an idea *why* the new D9 can mean higher production and more profits for you. For complete facts, see your Caterpillar Dealer. Ask for a demonstration and watch this giant eat up the work!

Caterpillar Tractor Co., Peoria, Illinois, U.S.A.

CATERPILLAR'S NO. 1 PROJECT

CATERPILLAR'S NUMBER ONE PROJECT A multimillion-dollar research and development program — to meet the continuing challenge of the greatest construction era in history with the most productive earthmoving machines ever developed.

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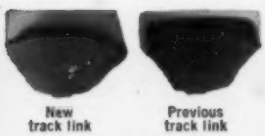
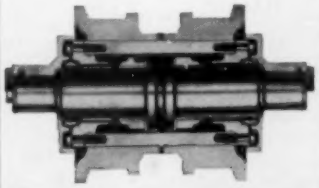
NEW D9 SERIES E— BORN OF RESEARCH PROVED IN THE FIELD



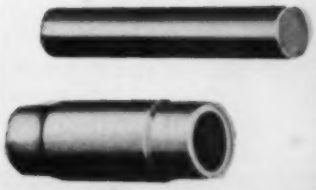
New track link — Previous track link

Light area at top indicates depth of hardening

New deep hardening steel. Caterpillar-developed steel alloy (plus more steel in stress areas) gives up to 40% longer life to track shoes, links and rollers.



Lifetime lubricated track rollers. Lifetime lubrication eliminates servicing problems. Oil is retained by dirt-proof, floating-ring seals.



Larger pins and bushings. Diameters are ¼" larger. Increased size reduces deflection and provides better contact along the length of the wear surfaces.

New seat adjustment. New spring-loaded adjustment mechanism provides more positive cushion and back rest positioning. Wider seat for more comfort.

Better visibility. Redesigned fuel tank gives better visibility to the rear and tapered hood offers unexcelled forward vision.

Stronger track shoes. New alloy permits deeper hardening in wear areas. Grouser height is increased ¾" for better penetration and prolonged service life.

New foot decelerator. Provides easier machine positioning. Allows deceleration without taking hands from controls (optional on direct drive, standard on others).

Bigger, heavier track links. Strength has been added in stress areas. Pitch increase from 9" to 10¼" strengthens all track components.

GALIGHER ENGINEERING | **CRACKS THE HARD ONES!**

Galigher engineers . . backed by skill, experience and world-wide prestige in all branches of metallurgy . . . carry on the Galigher tradition of meeting the exceptional challenge.

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Most of our many past assignments in ore beneficiation have been successfully solved through laboratory procedure. In many instances, however, our engineers have set up their equipment "on location" – in the field or at the mill.

If you require a service that always keeps an eye on the economics of operation, correspond with us or suggest a time and place for a conference.

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ABSTRACTS

Continued from page 975

cations of jobs: those which result from inspection and observation of equipment during operations and on down time; and those done in accordance with a specific time schedule. *AIME Colorado Section MBD Meeting, May 1959.*

Quicksilver in Oregon by *Howard C. Brooks*—Oregon mines have produced 101,783 flasks of quicksilver valued at approximately 14.1 million. Since 1927 when continuous production was begun in this state 98,542 flasks have been produced. Geology of the various deposits throughout the state is covered in detail. *Pacific Northwest Regional Conference, April 1959.*

Direct Reduction by the Tysland-Hole Electric Furnace by *Ola M. Roald*—Technical and economic factors during the last decade have had an important bearing upon determining the best process for making steel in the U. S. Direct reduction processes have been developed mainly in order to produce commercial grades of iron of high quality at competitive cost, to avoid dependence on a supply of high grade coke, and to achieve greater flexibility in the grade of ore used. The Tysland-Hole furnace, which was developed in order to take advantage of the possibilities of the Soderberg electrode, is described in detail. Furnace operation, end product, and by product are covered. The Tysland-Hole electric furnace method is compared with blast furnace methods of steelmaking, and the feasibility of the direct reduction method in the Pacific Northwest is discussed. *Pacific Northwest Regional Conference, April 1959.*

Control of Molybdenum in Uranium Circuits by *D'Arcy R. George*—All mills using the acid leach process recover uranium from their pregnant solutions by either solvent extraction or ion exchange and the presence of even small concentrations of molybdenum which occur in these liquors (probably as the polymolybdate anion,) interferes with their processing and increases operating costs. The source of molybdenum in domestic uranium ores, its mineralogy in the ores, solubility, purification of pregnant liquors, and control of molybdenum in yellow cake are covered in detail. Several methods for controlling molybdenum and uranium concentrates are suggested and discussed. *Fourth Annual Uranium Symposium, AIME Uranium Section, May 1959.*

Cleaning and Preparation of Metals for Electroplating by *E. B. Saubestre* and *H. B. Linford*—Wettability tests are the most convenient ones for detecting hydrophobic soils on metal surfaces. Further, it has been shown that when properly operated these tests can be made to be sensitive. Data as to the absolute sensitivity of various tests for cleanliness will be presented. The atomizer test, which is a variant of the water-break test, will be described. This is shown to be approximately ten times as sensitive as the old established water-break test. The reasons for this increased sensitivity have been postulated as, first, the atomizer test depends on the advancing contact angle whereas the water-break test depends on the receding contact angle, and second, bridging of small soiled areas is possible with the water-break test. However we have no examples where droplets of water have spread to cover even minute particles of comtamination.

Some studies of spreading rates or oils will be reported. The ease of cleaning of metal surfaces has been studied as a function of the spreading rate of the soil, for both pure compounds and mixtures of compounds. Results of studies on the adhesion of electrodeposits of nickel on copper will also be discussed. *Joint Meeting, SME, MBD-American Chemical Society, Div. of Colloid Chemistry, Atlantic City, N. J., September 1959.*

The Sensitivity of the Fracture Strength of Rock Salt to Environment by *E. S. Machlin*—Rock salt specimens, which have been subjected to a variety of surface treatments, and are then tested in three point bending in specific environments, are discussed in terms of their behavior. On the basis of these experiments, the known brittleness of rock salt in air is deduced to be a function of the zone or NO content of the air and not the O_2 or Ne content of the air. Further, it can be concluded on the basis of these results and supplementary tests in oxidizing solutions that rock salt is embrittled in the presence of active oxygen. The mechanism of the embrittling action of active oxygen is not known. *Joint Meeting, SME, MBD-American Chemical Society, Div. of Colloid Chemistry, Atlantic City, N. J., September 1959.*

MANUFACTURERS NEWS

NEWS / EQUIPMENT / CATALOGS

Mine Car Loader

Nolan Co. announces two new major developments in its automatic mine car loading station. Automatic selection of the stroke of the Porta-Feeder unit permits short and long cars in mixed trips to be fed and loaded without delay. Mixed and low cars can likewise be quickly loaded by instant automatic adjustment of the loading bar. **Circle No. 1.**

Coal Drill

An underground drill, capable of driving ventilation holes, burn holes, and escapeways at angles from 15° below horizontal to 90° above has

been introduced by *Salem Tool Co.* Compact drilling unit measures 68 x 48 x 96 in. Mast at vertical is just 7 ft 6 in. Separate 60-hp a-c or d-c power unit is 68 x 36 x 96 in. Both units are completely self-moving on skids and jacks. **Circle No. 2.**

One-Man Air Conditioner

Cool-headed earthmover operators are the object of a newly designed air conditioning unit by *Jamieson Laboratories.* Consisting of a helmet, hose refrigeration unit, and filter, the Jamieson Whitecap wires into any 12-v (or larger) ignition circuit. The company stresses that wearing the helmet will step

up driver efficiency in hot weather and eliminate the need for repeated costly rest periods. **Circle No. 3.**

New Crawlers

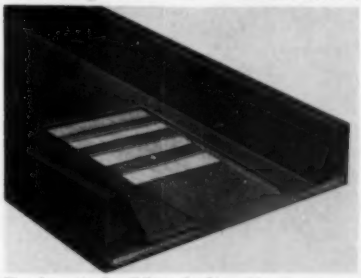
International Harvester is now turning out new International TD-9 and TD-6 crawler tractors, featuring 6-cyl, direct-starting diesels and new track rollers providing 500-hr lubrication intervals. The TD-9 pulls 11,720 lb at 1700 rpm; the TD-6, 8715 lb at 1550 rpm. Both are designed for fitting with a variety of dozers, loaders, and other attachments. **Circle No. 4.**

V-8 Diesel Scraper

The first production earthmoving scraper with a V-8 diesel engine, the new V-Power C Tournapull by *LeTourneau-Westinghouse* is teamed with a 20-cu yd C Fullpak scraper for a combination of large capacity and high power-to-weight ratio. The Tournapull can also be teamed with other trailing C units: the 22-ton rear dump and a 20-ton crane. **Circle No. 5.**

Trough-Edged Conveyor Belt

A patented flange edge conveyor belting from *MonoBelting Corp.* eliminates the use of troughing idlers, reducing maintenance expense and increasing belt life, according to its manufacturer.



Designated Monobelt, it is pretensioned to flex as it passes around the pulleys, eliminating fatigue and permitting faster belt speeds. Available in widths up to 48 in. **Circle No. 6.**

Deep-Hole Rotary Compressor

To meet the need for high pressure compressors in deep hole drilling, *Allis-Chalmers* has now developed a three-stage rotary compressor designed to furnish an automatically controlled, constant force of 250 psig, with momentary pressures up to 300 psig. The high pressure unit has the rotary compressor's advantage of not transmitting as much shock as other types. Plus feature: When worn, the sliding vanes of rotary units can be quickly replaced with minimum downtime. **Circle No. 7.**

Power Shift

Caterpillar D8 and D9 tractors are available now with power shift transmissions, providing instantaneous, one-lever control of gear shifting without interruption of power and momentum. Best features of both direct drive and torque converter power trains are combined by

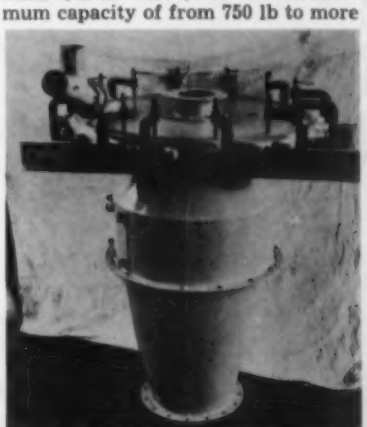
planetary gear set, which transmits a third of engine torque directly to transmission input shaft, and the remainder through the torque converter. **Circle No. 8.**

Portable Dredge

A new dredge by *American Marine & Machinery Co.* features a compact Hydra-Drive system which permits portability and two-day assembly. Complete machinery control system is housed in an elevated control room, giving full view of operations. **Circle No. 9.**

Biggest Micronizer

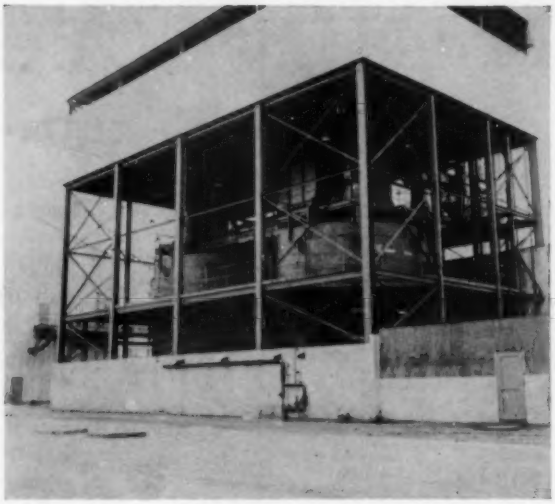
Sturtevant Mill Co. has shipped the biggest of its Micronizer fluid energy mills (42-in. diam). It has a maximum capacity of from 750 lb to more



than 3 tph, depending upon material and fineness desired. Using no moving parts, unit causes micro-grinding particle collision through jet action. **Circle No. 10.**

Skinner Furnaces

for Drying, Roasting, Calcining Incinerating and Decomposing



Two 23'6" I.D., 4 Hearth Skinner Furnaces drying over 40 tons of copper sulphide concentrates per hour.

Important Advantages

Flexibility. A wide range of possible combinations of diameter, number of hearths, number of burners, gas offtakes, up or down draft, rate of feed, retention time, etc., permit engineering a Skinner Furnace to the exact requirements of each individual application.

Accessibility. All wearing parts may be replaced without cleaning out or cooling down the furnace.

Minimum Dust Losses

Will Handle Sticky Material

Visibility. Access doors permit view and accessibility of material at each hearth.

Small Space. Minimum floor space per ton capacity.

2 to 14 Hearths.

4'0" to 23'6" Inside Diameter.

22 to 4000 sq. ft. Hearth Area.

Gas, Oil or Coal Fired.

Applications

Roasting Molybdenum Sulphide Concentrates
Roasting Uranium-Vanadium Ores
Drying Uranium-Oxide Precipitate
Decomposition of Oil Sludge
Lime Burning
Drying Copper Concentrates
Roasting Zinc Ores
Manganese Reduction
Dehydration of Alunite
Calcining of Basic Alum, Lime Sludges, Clays, Foundry Sand, Carbon, etc.
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PIC-A-PUMP: *Allis-Chalmers Mfg. Co.* has published its first complete catalog of pumping units, with 576 pages of engineering data covering hundreds of pump types, models, and sizes. A limited number of "Pic-A-Pump" catalogs are available to MINING ENGINEERING readers who request them on company letterheads. Write now to Allis-Chalmers Mfg. Co., Main Office, Box 512, Milwaukee 1, Wis.

(21) FACILITIES: *Lake Shore Inc.* has produced a new illustrated booklet which lists the company's complete manufacturing facilities including machinery, plants, supply and service centers, sales offices and products. Photos in the 12-page booklet show the large specialty machines in action.

(22) CRAWLER TRACTOR: Recently put into production by *International Harvester Co.* is the model T-340 31-hp (drawbar rating) crawler tractor designed for industrial use. It weighs only 5600 lb but has advantages of traction, stability, and maneuverability.

(23) AIR DRILL HOSE: *Hewitt-Robins Inc.* describes in 2-page bulletin S105 the Duroil air drill hose for pneumatic hammers. Rugged in construction yet light in weight, it is flexible and easy to handle.

(24) ROTARY DRILL: A single mobile rig from *Mobile Drilling Inc.* now does auger boring, core drilling, percussion drilling, and soil sampling, according to a folder from the firm. The B-52 Pacemaker pays for itself in performance and economy.

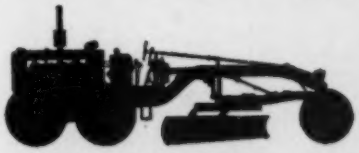
(25) VALVE: Automatic density discharge control for jig hutch products and similar applications is provided with the Dowsett valve from the *Denver Eqpt. Co.* Thickener, settling cone, and hydroclassifier underflow can be controlled and low-density underflows eliminated without the addition of expensive power units.

FREE LITERATURE

(26) GRINDER: A new grinder designed specifically for finishing crawler tractor rollers and idlers is now available from *L & B Welding Eqpt. Inc.* According to their data sheets, the machine is able to handle any size roller and idler.

(27) SEPARATORS: An exclusive feature of a line of tramp iron separators manufactured by *Stearns Magnetic Products* is the use of Indox ceramic permanent magnets. The ceramic material is barium ferrite. Data sheets give details.

(28) MOTOR GRADERS: Bulletin DE914 from *Caterpillar Tractor Co.* covers the main features of 3 motor



graders: No. 14, 150 hp; No. 12, 115 hp; and No. 112, 75 hp. Photographs and descriptions illustrate special features.

(29) DRILL: A heavy-duty sinker drill combining the Beavertail retainer with a new front head assembly has been developed by *Chicago Pneumatic Tool Co.* The company has details on the CP-69, emphasizes its versatility.

(30) COMPRESSOR: *Ingersoll-Rand Co.* announces the addition of a 250-cfm size to their line of Gyro-Flow compressors. The 250 is outlined in folder 2931. Offering 20 pct more capacity, the unit is smaller yet retains the same 1800-rpm engine speed. Special features are listed.

(31) INDUSTRIAL GASES: *Air Reduction Sales Co.* offers 32-page booklet ADC 892 covering all available industrial gases, illustrating in color how each gas is made, delivered, and used. Oxygen, nitrogen, argon, helium, acetylene are some of the gases covered.

(32) STRUCTURALS: Ideas that promote fast, economical building construction through the use of lightweight steel structurals are highlighted in a booklet published by *Jones & Laughlin Steel Corp.* Its 16 pages deals with junior beams, junior channels, joints, and light beam sections.

(33) TRAXCAVATOR: No. 933 series F Traxcavator from *Caterpillar Tractor Co.* is designed as an all-round digging and loading tool, according to information sheets from the manufacturer. Features include a new engine, stronger power train, larger-capacity bucket, and an operator's compartment built for maximum comfort.

(34) TUBE: A 19-page catalog entitled "Design and Cost Comparison of Heat Exchangers Using Wolverine Trufin" has been published by *Calumet & Hecla Inc.* Trufin, an integral finned tube, is explained and illustrated.

(35) HOISTS: To conserve time, reduce operating costs, and remove pressure from the busy shop crane, *Ingersoll-Rand Co.* has developed two lightweight, portable air hoists designed to be easily moved and installed. The 1000-lb capacity hoist weighs 39 lb and lifts its rated load at 45 fpm.

(36) VOLTAGE REGULATORS: Application, description, selection, weights, dimensions, and connection diagrams are included in a 60-page booklet from *General Electric Co.* describing dry type and liquid filled Inductrol voltage regulators (60 and 400 cycles).

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10

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41	42	43	44	45	46	47	48	49	50
51	52	53	54	55	56	57	58	59	60
61	62	63	64						

Students should write direct to manufacturer.

(37) LUBRICATING SYSTEMS: *Lincoln Engineering Co.* says it can bring cost-cutting efficiency with modern automatic power lubrication systems. Air, electric, and manually operated systems apply refinery-pure lubricant in measured quantities to all bearings in seconds while the equipment is operating. Ask for catalog 81, bulletin 811-R, and Lincoln's new "Report to Management."

(38) CYCLONE WASHER: The Dutch State Mines heavy medium cyclone washer for fine coal, ¾ in. to 48 mesh, is now available to coal producers in the U. S., according to a new brochure from *Roberts & Schaefer Co.* Predicted results of the washer with typical American coals are listed and a flow diagram is included.

(39) NOMOGRAM: A duel nomogram for horsepower, torque and rpm applicable to fractional horsepower motors and transmissions gives two scales each for torque and horsepower. Data is from *Merkle-Korff Gear Co.*

(40) DRILLING TOOLS: A flyer announces a line of *Brunner & Lay Inc.* rope thread blast hole drilling tools, Rok-Bits, Carbo-Rok extension steel, couplings and striking bars. Size and type specifications given.

(41) FILTERS: Automated features and labor saving design of the Eimco-Burwell filters are explained in an 8-page brochure from *Eimco Corp.* Drawings explain the plate and frame filtration method employed. Air flow, slurry flow, filtrate, cake, and washwater flow are designated by symbols or color. Ask for bulletin F-2052.

(42) DUST CONTROL: Data on dust control with Torit cyclone separators are available from *Torit Mfg. Co.* One or a combination of eight cyclone separators can protect machinery investment, product quality, employe health, and reduce maintenance cost.

(43) OFF-HIGHWAY TRANSPORTATION: *Easton Car Construction Co.* advertises truck bodies, trailers, and trailer trains, and automatic electric overhead dumping systems with pan-type trailers in catalog A. Charts and photographs illustrate the all-purpose models.

(44) SHUTTLE CAR & LOADER: Catalog G-143, covering the type 964 low vein loader, and catalog G-144 on the type 870-20 shuttle car have been published by *Goodman Mfg. Co.* The loader is low, has high capacity, power, and maneuverability. The low shuttle car has a 57-in.-wide conveyor and 4-ton capacity.

(45) BELT IDLER & CONVEYOR PULLEY: Bulletin 5980, 72 pages, has been released by *Chain Belt Co.* to detail Rex rated idlers and welded steel pulleys for belt conveyor, bucket elevator, and package duty service. A 10-page section outlines a method for selecting belt idlers to insure top performance.

(46) TRAILERS: Light, medium, and heavy-duty dump trailers tailor-made to fit specific hauling applications are featured in the booklet "Profitable Payloads" from *Hercules Steel Products Co.* Among the single and tandem axle models shown are steel and aluminum units of both frameless and frame-type design.

(47) BLOCKS & SHEAVES: *Sauerman Bros. Inc.* catalog I contains complete specifications including tonnage capacities and recommended wire rope sizes for Sauerman Durolite blocks and sheaves. Lightweight strength and durability are features.

(48) GOLD PLANTS: *Western-Knapp Engineering Co.* has made available bulletin K8-B12, "Gold Plants of the Future," reprinted from a paper presented at a meeting sponsored by the Colorado Mining Assn. The close degree of kinship between the extractive metallurgy of gold and uranium is discussed, with flow diagrams and cost study charts.

(49) REPAIR KIT: *Automatic Vulcanizers Corp.* now has on the market a conveyor belt repair kit consisting of chemically cold self-vulcanizing repair material under the Pang trade name. Data sheets and booklet tell how many problems of maintenance can be solved.

(50) BRUSH: *Osborn Mfg. Co.* has developed a low cost and efficient brush for cleaning clinging material from conveyor belting. Extruded aluminum mounting along with synthetic fill material provide fast, thorough cleaning action and long wear, according to the maker.

(51) OFF-HIGHWAY TRUCKS: *LeTourneau-Westinghouse Co.* offers a 24-page folder on the Haulpak truck line, illustrating unique Hydrair air-hydraulic suspension, high capacity V-frame and body, multiple braking system, and other special features.

(52) REPLACEMENT PARTS: *Columbia Steel Casting Co.* has produced a 4-page, 2-color brochure featuring replacement parts for tractors. A summary of Columbia's experience and skill is given and many photos illustrate the wide range of production capacities.

(53) PULLEYS: *Stearns Magnetic Products* has announced the development of a line of electromagnetic pulleys for removing tramp iron from belt-conveyed bulk materials. It retains the advantages of two-coil design and gives more protection per dollar. Ask for bulletin 1011.

(54) CAR SHAKER: The A-C line of car shakers for safe, fast, and economical pushbutton unloading of granular material from open, hopper-bottom gondola railroad cars has been expanded with a new unit according to data sheets from *Allis-Chalmers Mfg. Co.* The 3½ ton shaker is designed for small and medium operations and is capable of handling the same materials as the 5-ton unit, but at a slower rate.

(55) BUCKET: One-piece cast manganese steel backhoe buckets are now available from American Manganese Steel Div. of *American Brake Shoe Co.* The arch is cast with a box cross-section to provide greater strength. Further information is available from the manufacturer.

(56) EXPLOSIVES: "Du Pont Explosive Forming," a pamphlet explaining metal forming techniques, is offered by *E. I. du Pont de Nemours & Co.* Charts, diagrams, and complete instructions fill the booklet.

(57) CRUSHING EQUIPMENT: Latest addition to the line of crushing equipment of *Staub Mfg. Co. Inc.* is the Kue-Ken portable primary. Advantages include high capacity and low maintenance costs in various sizes and combinations of components. Ask for data sheets.

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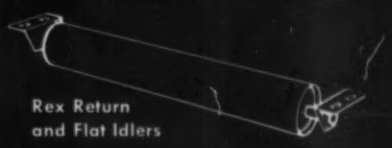
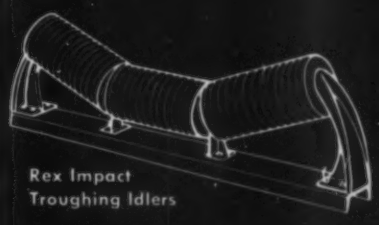


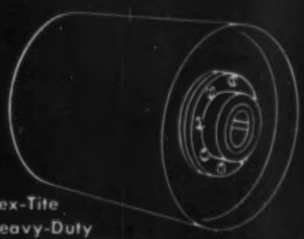
Rex Return and Flat Idlers

Rex Belt Training Troughing Idlers



Rex Impact Troughing Idlers

Rex Spiral Return Idlers



Rex-Tite Heavy-Duty Conveyor Pulleys

Rex Taper-Lock Normal-Duty Conveyor Pulleys

CALL THE MAN WHO

makes your conveyor dollar carry more, last longer

Here's how you can be sure of top conveyor efficiency and economy: include a CHAIN Belt Conveying Engineer on your planning team. He's well qualified in two ways to help your team find the right system for your specific needs: 1. He offers you the industry's most complete selection of belt conveyor components such as idlers, pulleys, bearings and take-ups—assuring the most efficient design for every application. 2. He's an application expert—offering you many years of experience in selecting the right conveyor system for the job.

As a result, you get top efficiency in your system and you save because you cut initial, operating and maintenance costs. You keep down time to a minimum with trouble-free operation and longer conveyor life. You move maximum tons at lowest cost.

Whether you are planning a new system or expanding existing units, call in your CHAIN Belt Conveying Engineer. He will help your planning team get better results. Contact your nearest CHAIN Belt District Office. Or write CHAIN Belt Company, 4794 W. Greenfield Ave., Milwaukee 1, Wis. In Canada: CHAIN Belt (Canada) Ltd., 1181 Sheppard Ave. East, Toronto.

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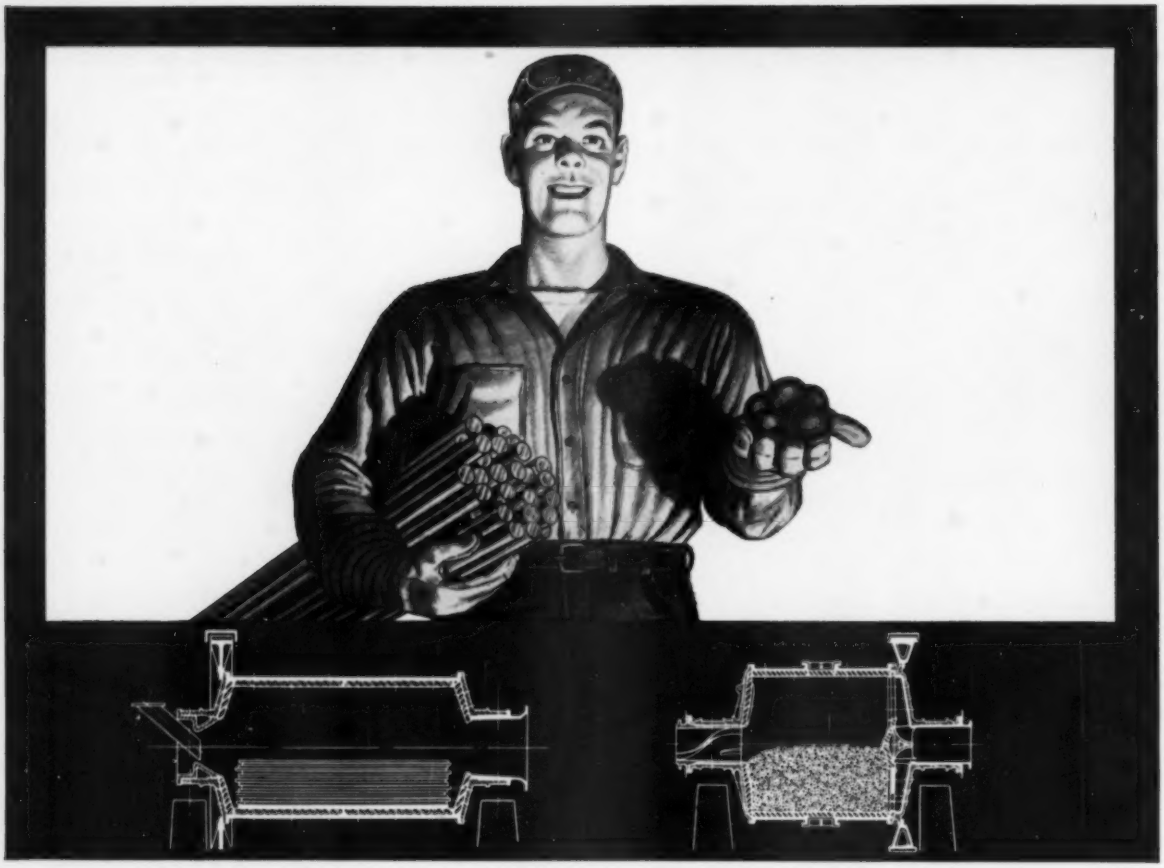

Increase grinding mill efficiency... *with* CF&I Grinding Media

The Image of CF&I helps assure increased output in grinding mill operations—through the use of long-wearing, tough CF&I Grinding Balls and Grinding Rods.

The special analysis steels used in these products give an ideal balance between hardness and toughness—thus affording optimum grinding ability plus maximum wearability.

CF&I GRINDING BALLS are hot-forged and carefully inspected throughout production and immediately before shipment to assure that they are free of surface pits, circumferential ridges or other surface imperfections. They have excellent resistance to both abrasion and impact, and operate economically in either high or low speed mills. Available in diameters from ¾" to 5".

CF&I GRINDING RODS are hot-rolled of a special long-wearing steel which minimizes both bending and premature breakage. All rod ends are square cut and rods are of proper length to fit the mill in which they will operate. All rods are machine straightened to assure maximum line contact between the rods for the full length of the mill. These properties help facilitate rod line-up in the mill and eliminate tangling of the charge. Available in ½" increment sizes from 1½" to 4" in diameter and in various lengths.

For complete information and service on all CF&I Mining Products, contact the nearest CF&I sales representative.

OTHER CF&I STEEL PRODUCTS FOR THE MINING INDUSTRY
CF&I Mine Rail and Accessories • CF&I Rock Bolts and Realock Metallic Fabric
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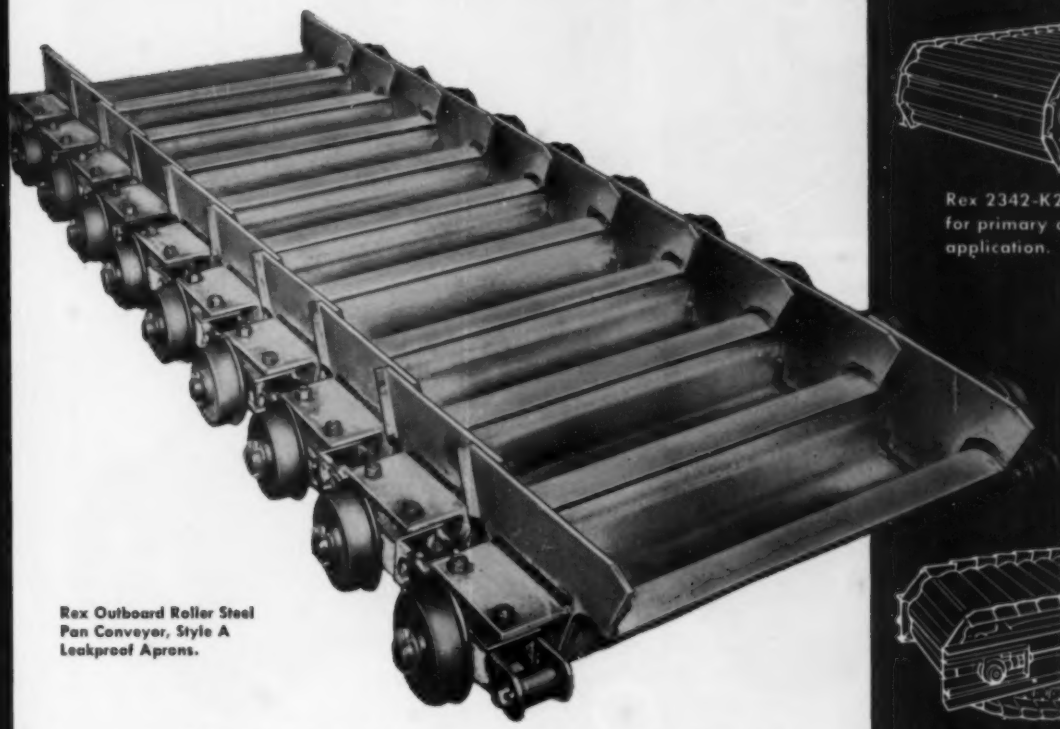
Another PLUS value...

How to convey hot bulk materials with initial temperatures up to 1900°



Rex Outboard Roller Steel Pan Conveyor, Style A Leakproof Aprons.

Rex Outboard Roller Steel Pan Conveyors provide a practical solution to many unusual conveyor problems.

Unique construction assures longer life—eliminates many replacement costs down through the years—holds down time and maintenance costs to a minimum.

Here are two of the ways improved Rex design gets right to the heart of the heat problem:

1. Chain and rollers are insulated from maximum temperature heat zone.
2. Carbon steel pans, with large pan surfaces, provide maximum heat transfer.

Long wear life, easy maintenance—Ruggedly built for extra stamina, Rex Outboard Roller Steel Pan Conveyors are known for their long, trouble-free service. Wear is confined to heavy outboard rollers; square through rods connecting the chains assure rigidity, equal load distribution; and outboard roller design permits easy servicing without disassembly of chain or conveyor.

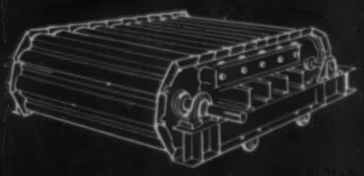
Preferred throughout industry—Deep pan construction, shown above, is ideally suited for use in a wide range of heat processing applications; for example: calcining, sintering, briquetting, beneficiating and nodulizing. This style is available in a wide range of sizes.

Other types available for every service—For information on how Rex Apron Feeders, Apron and Pan Conveyors can help you cut production costs, write CHAIN Belt Company, 4716 W. Greenfield Ave., Milwaukee 1, Wis. In Canada: CHAIN Belt (Canada) Ltd., 1181 Sheppard Ave. East, Toronto.

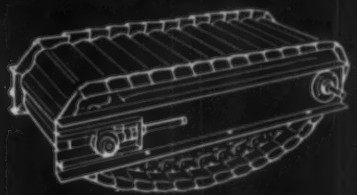
REX®

OUTBOARD ROLLER STEEL PAN CONVEYOR

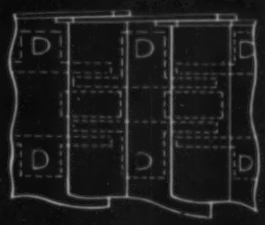
Types For EVERY Service

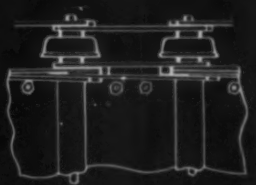


Rex 2342-K21 Heavy-Duty Feeder for primary or secondary application.



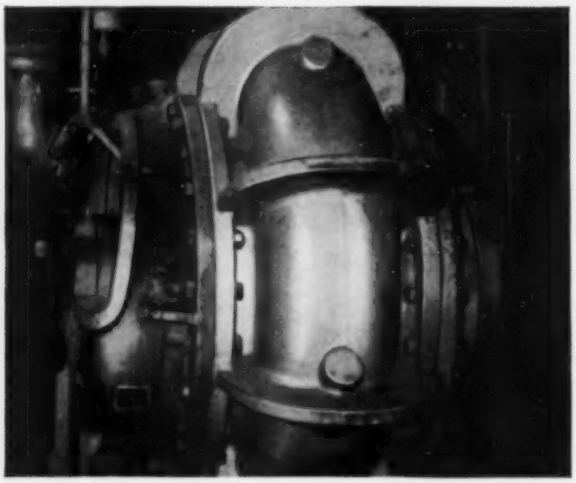
Rex 531-K17 Light-Duty Apron Feeder, used under hoppers and bins to regulate material flow.



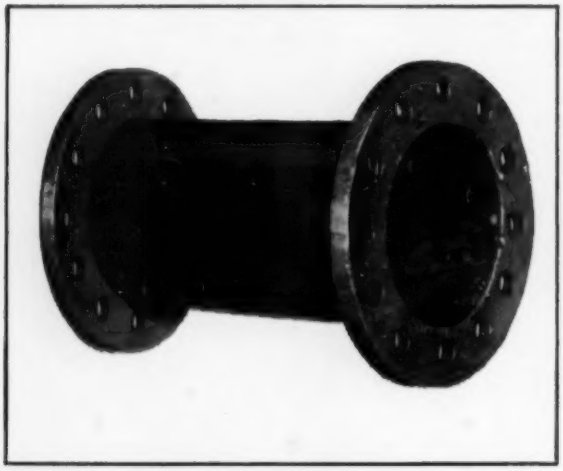


Style A aprons with Type K or A chain attachments furnished as machinery parts for many applications.

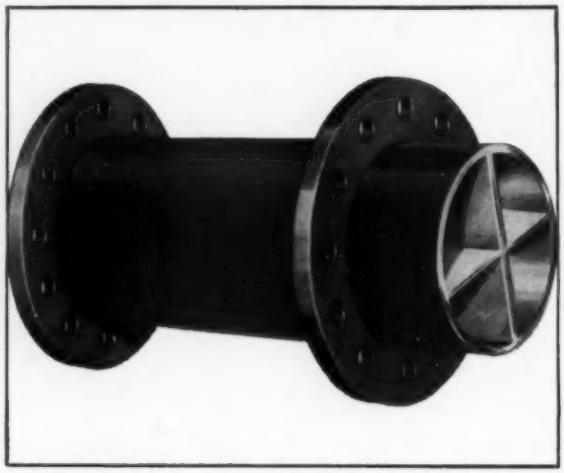
1. This thick slurry (28% solids) comes from a coal washing process half a mile away.



2. To stand its grinding action, this 2600 gpm pump is fitted with Ni-Hard impellers and casings.



3. So when fast-running slurry caused heavy wear in the suction-side piping of these pumps . . .



4. It was easy to answer the problem by inserting baffles and sleeves of Ni-Hard iron.

How Ni-Hard Castings Beat Wear Problem— Reduce Maintenance In Coal Washing System

One of the largest hydraulic refuse-handling systems relies on outstanding abrasion resistance of Ni-Hard iron to dispose of 160 tons per hour of tailings.

The Sunnyhill Coal Company in New Lexington, Ohio has one of the largest hydraulic refuse - handling systems in the coal industry . . . and with the help of Ni-Hard* nickel-chromium cast iron, it is one of the most efficient.

The system's three solids-handling pumps, built by Barrett-Haentjens & Co. of Hazelton, Pa., are well protected against swiftly moving streams of abrasive tailings. All impellers and casings are made of Ni-Hard iron, the outstanding alloy for abrasion protection.

Materials rejected in the coal washing process — rock, shale, sand and other waste — mixed with water, swirl through the pipelines at high speed. This once caused heavy wear in the suction line . . . until Barrett-Haentjens installed a cross-shaped baffle of Ni-Hard iron mounted in a Ni-Hard sleeve inside the regular cast iron pipe. Action of the baffle in curbing turbulence and the superior abrasion resistance of Ni-Hard iron combined to beat the wear and maintenance problems.

If you are experiencing severe wear in pumps and lines, and shutdowns for repairs are too frequent — it will pay you to consider long-wearing Ni-Hard cast iron for your operations.

Ni-Hard castings are available from authorized producers throughout the country. For the address of the one nearest you, write to Inco.

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NICKEL MAKES STEEL PERFORM BETTER LONGER

To Recover Iron from Copper Slag Piles

A projected mill to recover iron from the waste slag of the old United Verde copper smelter at Clarkdale, Ariz., will be the first of several possible facilities designed to process slags by the Strategic-Udy direct reduction process. The Clarkdale project involves building Arizona's first integrated steel plant and will be based on the potential wealth of a 30-million ton pile of slag averaging about 33 pct Fe, 0.5 pct Cu, and 2 pct Zn. The mill builder, Webb & Knapp Strategic Corp., a new subsidiary of Webb & Knapp Inc., also has plans for constructing a steel mill at Anaconda, Mont., where it has already contracted to buy 40 million tons of slag from the Anaconda Co. The Clarkdale mill will cost more than $15 million and is expected to begin operating in about two years, if financing is available.

Inland Steel Joins Wabush Developers

Inland Steel Co. is to become a 10-pct owner in Wabush Iron Co. Ltd., a company engaged in investigating the potential of a large Labrador iron orebody. Inland is joining four other U. S. and Canadian firms as a part owner of Wabush, which is currently building a pilot plant that will turn out concentrate for large-scale testing next year.

Beryllium Flotation Reagent Reported

A newly formed beryllium mining and milling company, Dynamic Metals Corp., reportedly has exclusive rights to a beryl flotation reagent, which could eliminate hand-cobbing—until now the only commercial concentration method. The new company was formed by Radorock Resources Inc., Federal Uranium Corp., Lisbon Uranium Corp., and Hidden Splendor Mining Co.

Simple Method for High Purity Tungsten, Molybdenum Powders

Using a method called fused salt bath electrolysis, USBM metallurgists in Reno, Nev., have treated scheelites and obtained 98-pct pure molybdenum and 99+-pct pure tungsten. Concentrate, mixed with alkali phosphates or borates, is heated and subjected to electrolysis under low voltage. Molybdenum then collects on the cathode, which is removed. A new cathode is inserted and the voltage is stepped up. The higher voltage brings about the recovery of tungsten in the solution, completing the processing. Economy of the method indicates possible commercial use.

TVA Lets Big Contract to Peabody Coal

Peabody Coal Co. has signed a contract with the Tennessee Valley Authority involving supply of 65 million tons of coal to a steam-electric plant, over a period of 17 years. Coal will be delivered, unwashed, to a new plant for $2.95 a ton. Cost is low because the truck haul from mine to generating plant is only five miles at most.

Tax Help for Intermediate Ores on Iron Range

The same Minnesota law that helped increase research and development on taconites in the early forties, has been amended to lend tax assistance in developing processes for using the soft, lowgrade intermediate ores of the Iron Range.

Comilog Manganese Reserves

Huge reserves have been estimated for Comilog's high grade manganese deposits in the Gabon Republic of Africa. Of the four plateaus covered by the ore-bearing area, two have been covered only by rapid exploration. The other two, investigators have shown, include proven reserves of more than 70 million long tons, probable reserves of similar tonnage, and possible reserves of about 50 million tons. One area, only a kilometer square, holds a reserve of 9 million long tons.

"Spotty, as a digger, you just ain't got it!"

Without realizing it, Billy has hit upon a basic truth in the excavating business. To come out on top, you've got to use the best equipment for the job.

With many factors beyond a contractor's control, choosing the right equipment becomes especially important. For this is one thing a man *can* control.

That's why so many contractors choose Bucyrus-Erie. They have learned . . . as their fathers did before them . . . that B-E machines are built for more than ordinary digging. They are built to handle the toughest jobs — and still perform better.

BUCYRUS ERIE

NOW—

The EIMCOBELT® Filter

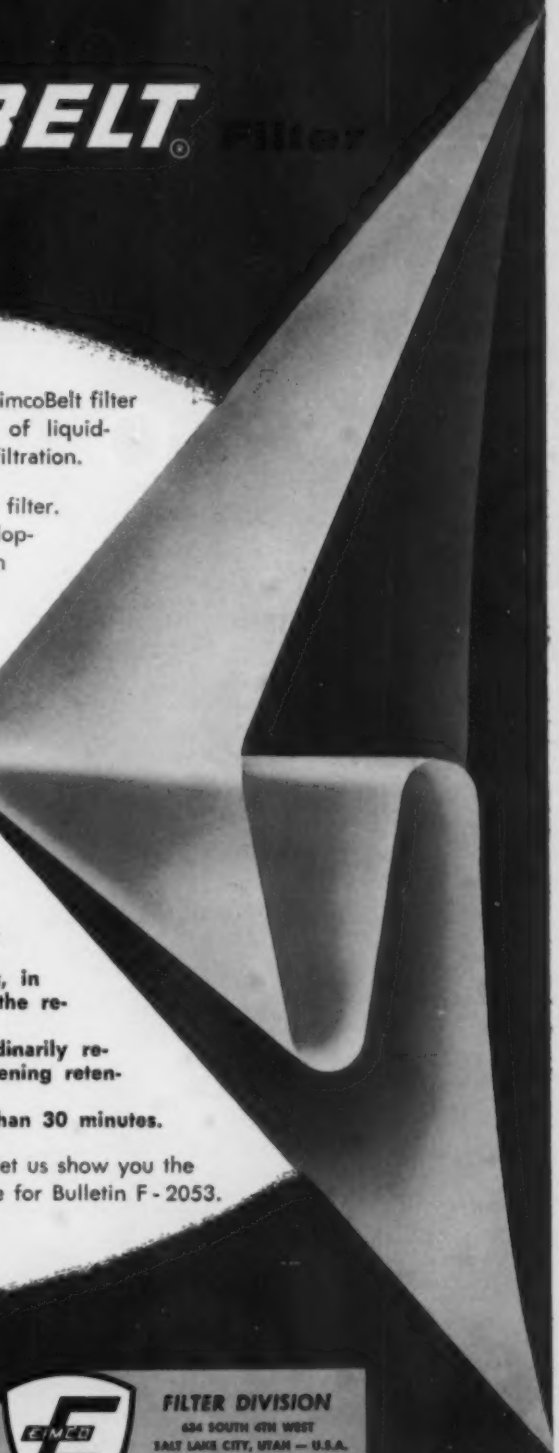
The Eimco Corporation is proud to announce the EimcoBelt filter . . . an important achievement in the science of liquid-solids separation through continuous vacuum filtration.

EimcoBelt is a perfected continuous belt drum filter. It was developed in Eimco's Research and Development Center at Palatine, Illinois, in cooperation with Eimco design engineers at the factory, who worked for more than six years with a budget of over a million dollars to create, field test, and perfect this revolutionary new filter.

The EimcoBelt, equipped with cloth or metallic medium, eliminates blinding. The medium is removed from the drum every filter cycle for cake discharge and cloth cleaning.

- **Thin cakes are easily discharged.**
- **High vacuums, and high cake washing efficiencies, are maintained.**
- **Capacities are greatly increased, permitting, in many cases, the use of smaller filters for the required tonnage.**
- **Slurries with low density solids, which ordinarily require thickening, can be filtered, and thickening retention time eliminated.**
- **Cloth change can be accomplished in less than 30 minutes.**

If you use filtration in any of your processing, let us show you the advantages of the EimcoBelt. Write for Bulletin F-2053.



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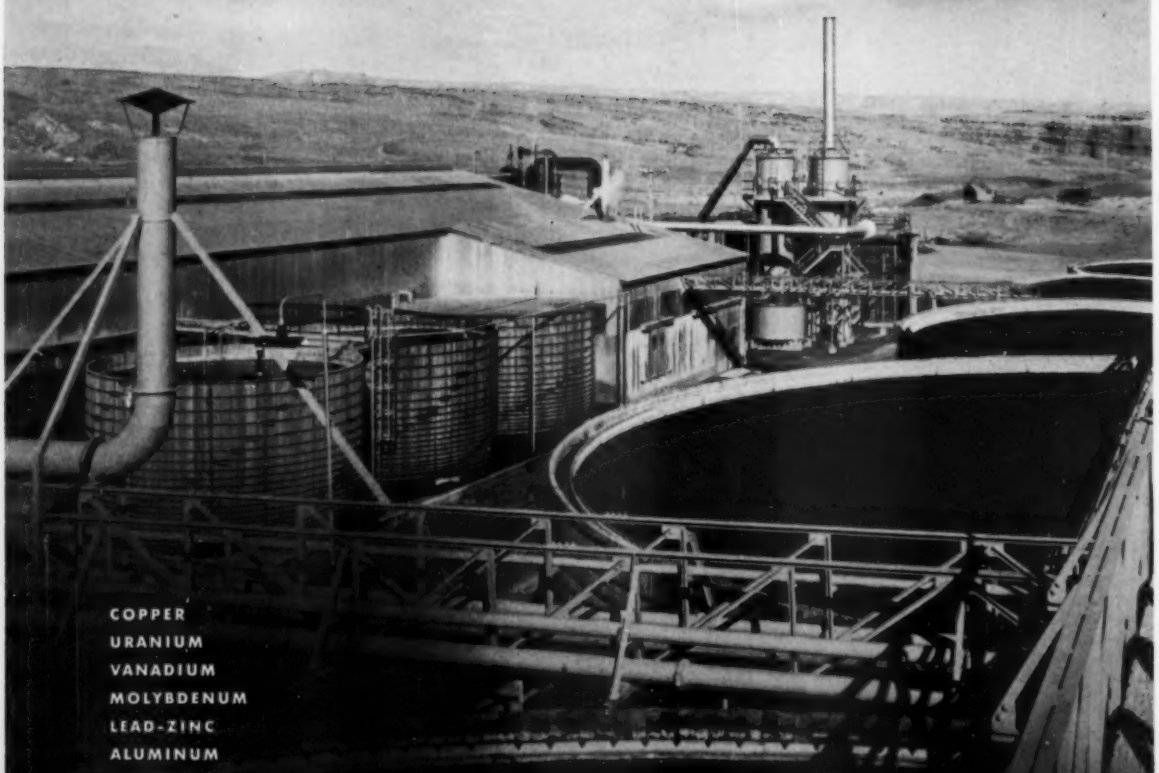
For progressive design, for professional engineering services, and for a profitable operating plant, Stearns-Roger is the logical one-source answer. Over 70 years experience in the design and construction of metallurgical, mineral and chemical beneficiation plants, small and large, assurance that for you, too, Stearns-Roger can design to your flowsheet, engineer, fabricate, and erect a modern processing plant.



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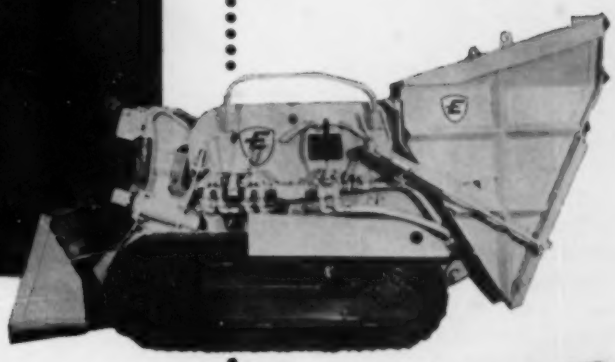

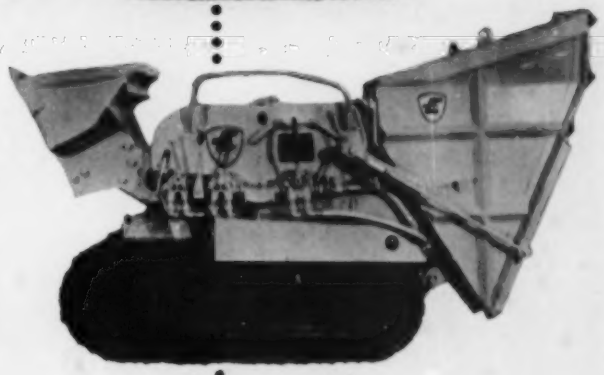

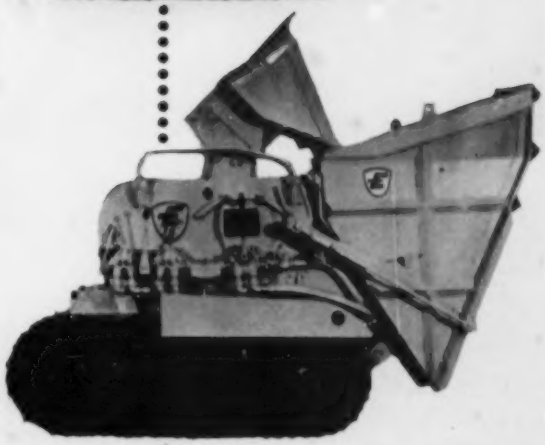

GREATER PRODUCTION WITH EIMCO 631

. . . crawler mounted hopper loader with greater capacity

Latest addition to the famous 630 series of compressed air activated, crawler mounted equipment, with a greater hopper capacity of 45 cubic feet. With an additional 5 cubic feet carried in the bucket, a payload of three tons (50 cubic feet), can be easily handled. The 631 will also be available for AC operation.

The Eimco 631 is self-loading, capable of both loading and carrying material. It is the answer to many and varied problems of developing and production-loading in stopes, drawpoints and other such areas.

Features include special long tracks for maximum stability and ground contact area; a positive semi-automatic hold-device, for holding loaded bucket in carrying position; heavy-duty and removable hopper with full opening door; improved, heavier equalizer bar; new, improved trunnions and brackets and additional track rollers for a crawler base capable of easily carrying these heavier loads.

Contact the nearest sales office or write The Eimco Corporation, P.O. Box 300, Salt Lake City 10, Utah, for all details.

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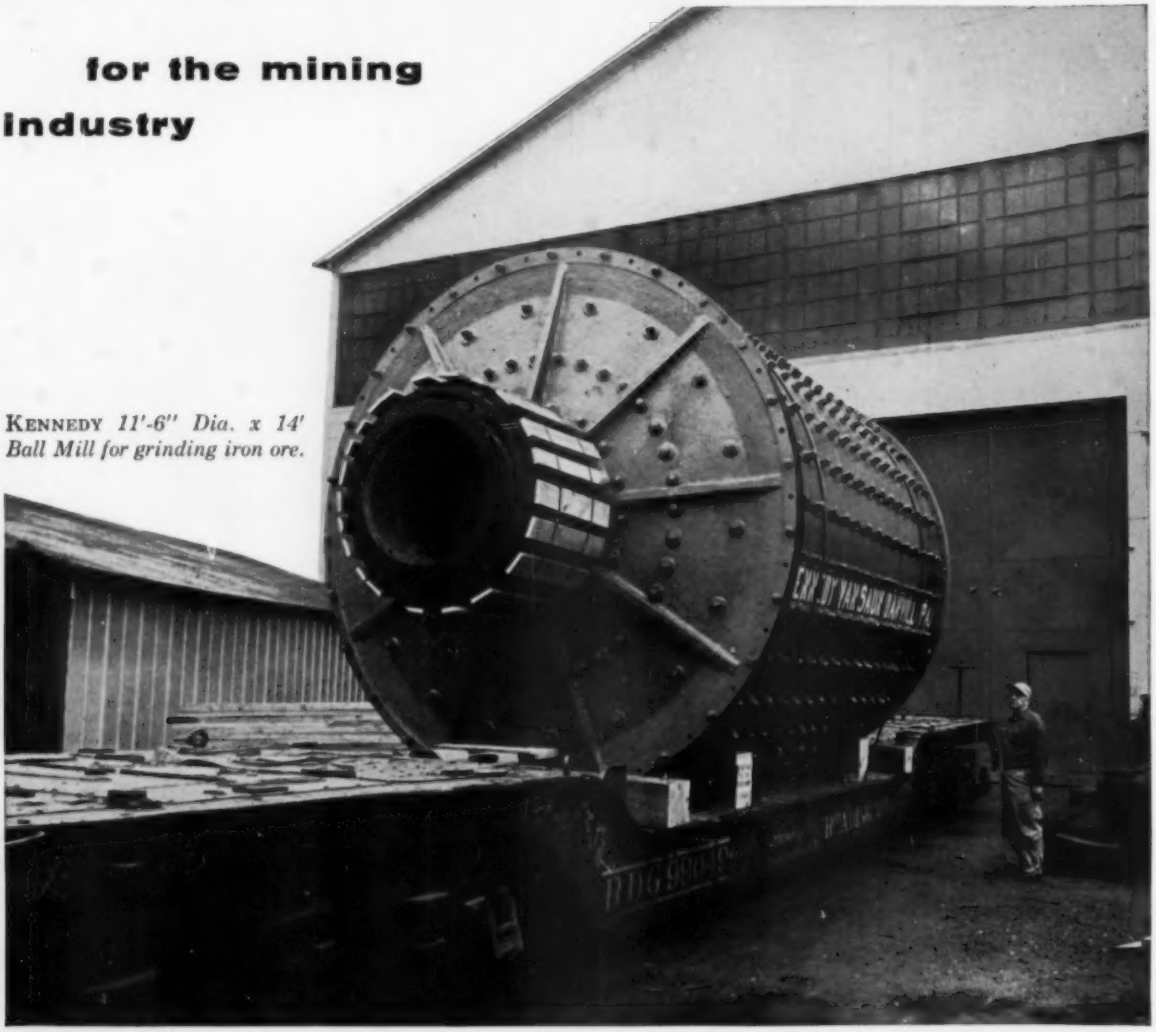
KENNEDY BALL MILLS

for the mining industry



KENNEDY *11'-6" Dia. x 14' Ball Mill for grinding iron ore.*

Dependable operation in wet or dry grinding of material at low cost, with minimum maintenance—this is the reputation that KENNEDY Ball Mills enjoy.

You can profit from this reputation by specifying KENNEDY.

Send for complete information on KENNEDY *equipment.*

FEATURES THAT DISTINGUISH KENNEDY GRINDING MILLS

- Cast steel or Meehanite heads
- Welded and stress-relieved heavy steel plate shells
- Large diameter trunnions
- Self-aligning bearings with adjustable sole plates
- Positive "Ferris Wheel" lubrication of main bearings
- Oil-tight bearing seals
- Motorized hydraulic lift to reduce starting torque
- Single helical cast steel gear and pinion

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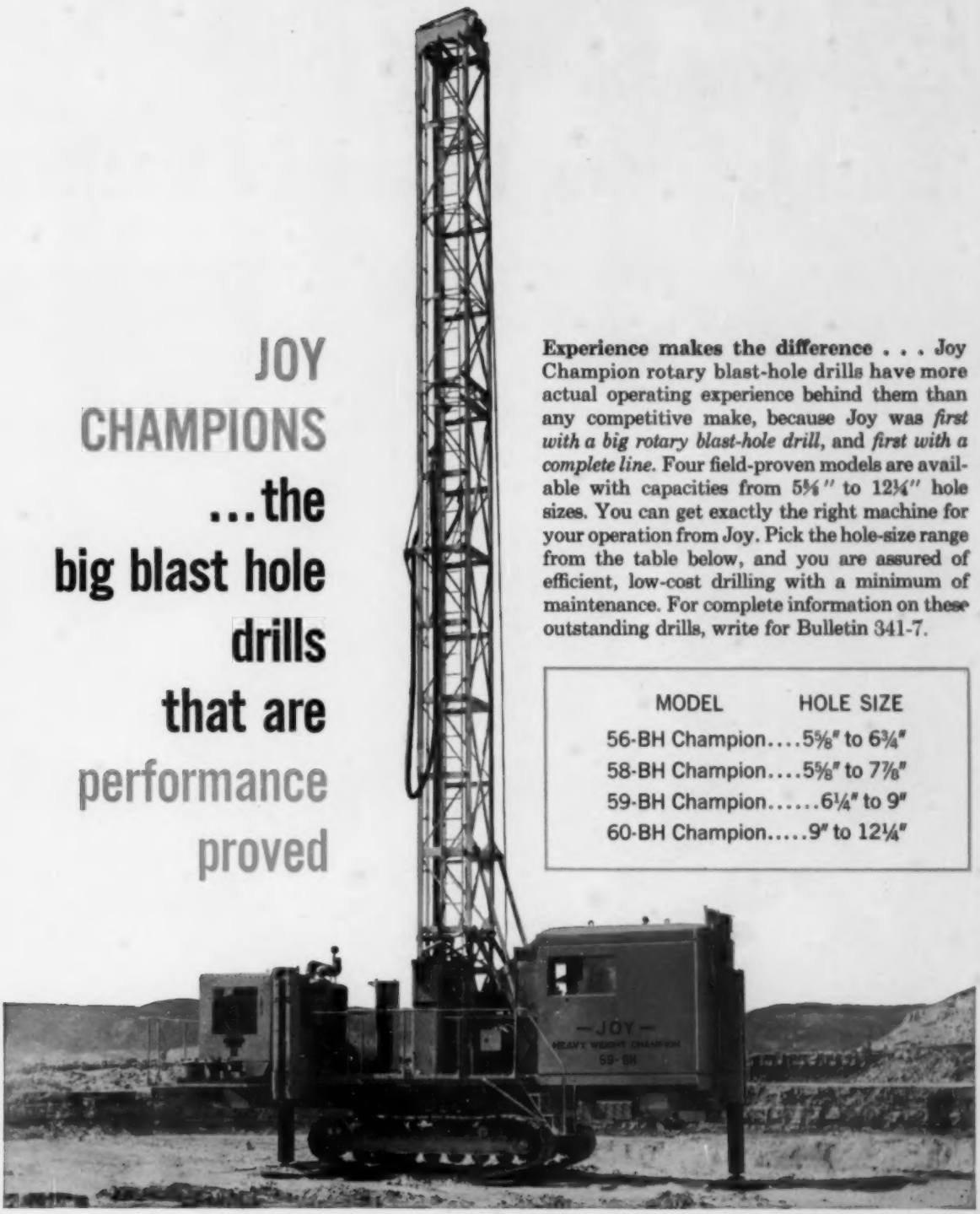
JOY CHAMPIONS ...the big blast hole drills that are performance proved

Experience makes the difference . . . Joy Champion rotary blast-hole drills have more actual operating experience behind them than any competitive make, because Joy was *first with a big rotary blast-hole drill*, and *first with a complete line.* Four field-proven models are available with capacities from 5⅛" to 12¼" hole sizes. You can get exactly the right machine for your operation from Joy. Pick the hole-size range from the table below, and you are assured of efficient, low-cost drilling with a minimum of maintenance. For complete information on these outstanding drills, write for Bulletin 341-7.

MODEL	HOLE SIZE
56-BH Champion	5⅝" to 6¾"
58-BH Champion	5⅝" to 7⅞"
59-BH Champion	6¼" to 9"
60-BH Champion	9" to 12¼"



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*PAYS OFF FOR YOU AGAIN**

New Cat Power Shift Transmission for D9 and D8 Tractors

CONTROL is mounted to the left of the operator. One selector lever eliminates gearshift, forward-reverse and flywheel clutch levers. The safety lever prevents accidental transmission engagement. The selector lever moves in a "U" path to various positions. To the left are three reverse speeds. To the right, three forward speeds. To change speed, simply move lever to the required position. To change travel direction, move lever to the opposite side. Changing speed and direction are as easy as that—without clutching—changes can be made while the machine is in motion under full load without loss of power or momentum.

HIGHER PRODUCTION PUSHLOADING: Power is quickly, easily adjusted to meet the demand. Shifting to higher gear boosts scraper out of cut quickly at higher speed. Speedy reverse quickly positions machine for next push.

HIGHER PRODUCTION BULLDOZING: As material builds up, Cat power shift transmission permits split-second shifting. There's a minimum of forward surge when the load is dropped. Instant reversing further slashes cycle time.

- **Shifts on-the-go under full load in a split-second!**
- **Changes speed, reverses direction with finger-tip control lever—and no clutching!**

The wraps are off—it's ready. After many years of research and on-the-job testing, Caterpillar now offers a revolutionary new drive for Cat D9 and D8 Tractors—power shift transmission. This new transmission—with an exclusive design—provides production highs never before possible with a track-type tractor. Here's why:

1. It combines for the *first* time the flexibility and anti-stall features of torque converter with the operating snap of direct drive. Because of its direct drive characteristics, it is more efficient than other power shifts.

2. With one control lever and no clutching, it reverses direction . . . changes speed . . . smoothly . . . under full load . . . in a fraction of a second.

Talk about productivity—the Cat power shift transmission delivers in a big way. Split-second on-the-go shifts give plenty of power in the highest gear possible. Shifting is so easy the operator just naturally gets more work out of the tractor. What's more, he gets it on the toughest, most demanding track-type jobs.

Besides the power shift transmission, you also have your choice of direct drive or torque converter in the D9 or D8. For complete facts on the new Cat power shift transmission see your Caterpillar Dealer. He's ready to explain in detail how it works, or to demonstrate its ruggedness . . . its ease of operation . . . its productivity. Name the date—he'll demonstrate!

Caterpillar Tractor Co., Peoria, Illinois, U. S. A.

CATERPILLAR

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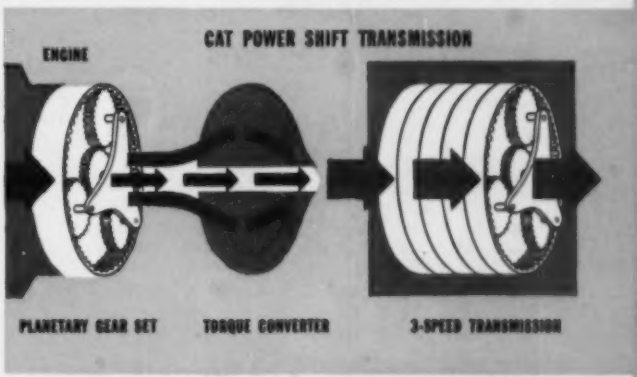
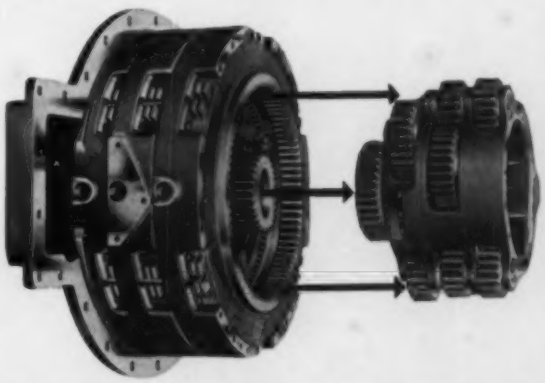
DIESEL ENGINES • TRACTORS • MOTOR GRADERS

EARTHMOVING EQUIPMENT

BORN OF RESEARCH
PROVED IN THE FIELD



BASIC DESIGN: Total power is transmitted from the engine to a planetary gear arrangement mounted in the engine flywheel. The planetary divides and directs the total power—part goes through a direct drive shaft straight to the transmission and the remainder through a torque converter to the transmission. This enables the Cat power shift transmission to combine the snap and positive operating feel of direct drive with the anti-stall and flexibility features of torque converter drive. Its clean, unit construction design makes it easy to service, when required.



ONE TON OF RUGGEDNESS: Here's a portion of the components that make up the new Cat power shift transmission. Designed and built specifically by Caterpillar for its giant tractors, this rugged transmission weighs well over a ton. Every component is constructed for long-lived service. Selected alloy steel insures a transmission that stands up under the toughest conditions. Equally important, Cat power shift transmission comes to you thoroughly tested by exacting design and demanding field work in the heaviest earthmoving duty.

***CATERPILLAR'S NO. 1 PROJECT:** A multimillion-dollar research program—to meet the continuing challenge of the greatest construction era in history with the most productive earthmoving machines ever developed.

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metal mining modernization

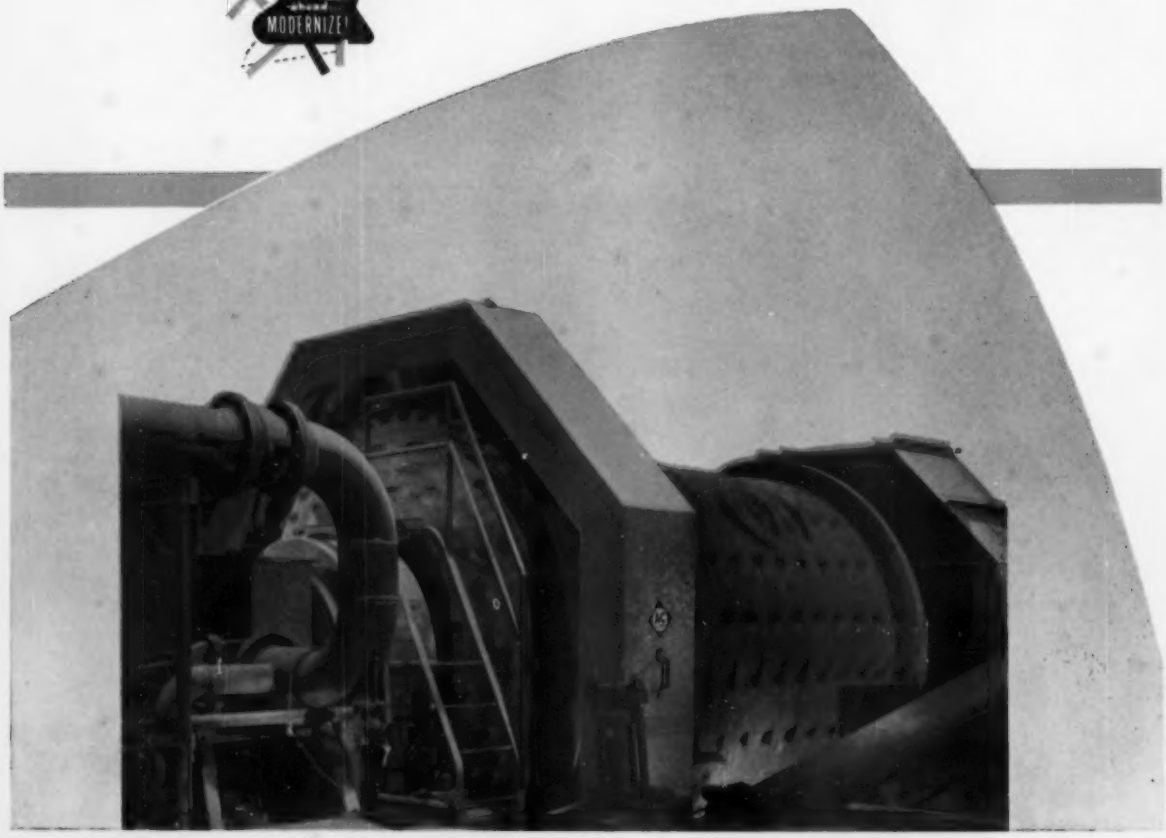
Grinding mills grow... Operating costs shrink

2000-hp mill does work of multiple units ...at far less cost

It's the big mill that grinds out profits. Want proof? In a typical installation, a giant 13 by 20-ft, 2000-hp Allis-Chalmers mill replaced two 10½ by 17 units. Operating costs were cut by a whopping 25% without losing one ounce of capacity.

Grinding mills are on the grow. The single mill conserves floor space and affords better quality control with its improved circuits. Watch for the 2500 and 3000-hp Allis-Chalmers mills soon to be announced.

Plan to stay ahead... MODERNIZE!



See your A-C representative or write Allis-Chalmers, Industrial Equipment Division, Milwaukee 1, Wisconsin. In Canada, write Canadian Allis-Chalmers Ltd., Box 37, Montreal, Quebec.

ALLIS-CHALMERS A-C ALLIS-CHALMERS

A-5936

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MINING engineering **DRIFT**

EDUCATION AND PUBLIC RESPONSIBILITY

A recent publication, *Education for Public Responsibility*, has been issued by the Fund for Adult Education. The FAE was established by the Ford Foundation in 1951 to "help expand educational opportunities for leaders—and emerging leaders—in all fields of American life to better understand and meet their public responsibilities." To quote from this pamphlet:

"Man now faces opportunities never known before . . . He can think of reaching toward the stars—figuratively and literally.

This same man faces challenges never known before. There is an ever-present danger of a nuclear war . . . With or without war, there is danger of grim tyranny over all mankind.

If man is to make use of his opportunities and meet his challenges, he must match his expanding knowledge and increasing control of physical nature with expanding self-knowledge and increasing self-control. Those who believe that this can be done only through human freedom are called upon not only to do the best they know how, but also to find and develop new resources of will, courage and wisdom.

Belief in human freedom is belief in the capacities of the individual: . . . Belief in the capacities of the individual is belief in the power of education. . . . .

Our society embraces many philosophies and religions. We have a decentralized and diversified system of education. We have a privately operated system of information and opinion.

All citizens share in the rights and duties of political self-government. . . .

All citizens share in the rights and duties of our economic system based upon free choice. . . .

We have opportunity, through active participation in many non-governmental organizations, to set and to strive to realize great social goals.

All these opportunities dictate responsibilities equally great.

And these responsibilities—the vital requirements of freedom itself—are continually growing in size and complexity. . . .

We must make proper use of expert knowledge, yet preserve control by the people.

We must give freedom of opportunity for exceptional talents, yet provide equality of basic opportunities for all.

We must develop more effective cooperative action while enhancing individuality.

On the world scene, the future of the American people and the future of all other peoples are intimately involved one with another. The United States has become the leader of the free peoples of the world and the hope of those who want to be free. Therefore, a high order of public responsibility would be required of us even if the Soviet Union and its satellite nations were not bidding to rule the world. But they *are* seeking world domination.

While their obvious threat is physical, their more subtle challenge is in the realms of beliefs and values. They challenge our fundamental conviction that free people can govern themselves. While always ready to use their military might, they patiently wait . . .

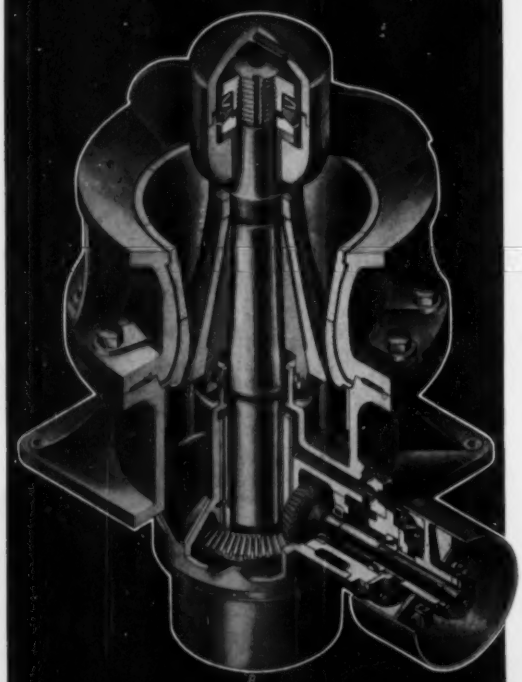
The capabilities of the Soviet society rest squarely upon Soviet education. Soviet achievements . . . attest the effectiveness of this Soviet resolve to make education a disciplined instrument of national purpose.

This danger gives an urgency to our meeting the requirements which are inherent in freedom. Our education—dedicated to freedom—must be as purposeful and as effective as communist education for servitude.

Yet clearly our education cannot be imitative. As our principles and purposes are profoundly different, so, too, must be our practices.

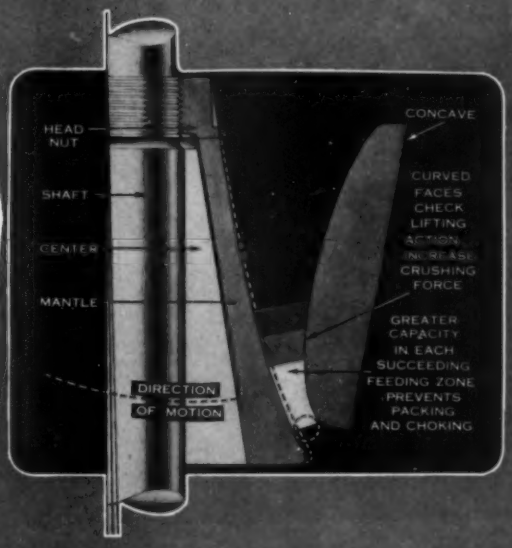
If tyranny is to work, men must be tutored in totalitarianism. If freedom is to work, education enabling individuals to develop their greatest potentialities—and inspiring them freely to serve the welfare of their society—is indispensable."

type TY
GYRATORY CRUSHER



Traylor-made
for uniform secondary reduction

Traylor TY Reduction Crushers require minimum floor space and little head room, with features that combine high production, economy of operation and lower maintenance costs.



Traylor's curved concaves used in the TY Crusher enable operators to secure large tonnages of small product of uniform size with low percentage of oversize and waste fines. Traylor TY Reduction Crushers are built in six sizes from 1'-3" to 5'-6" and with feed openings from 3" to 22". Write for bulletin #8112 today!

Traylor

ENGINEERING & MFG. CO.

1203 MILL ST., ALLENTOWN, PA.

Sales Offices: New York — Chicago — San Francisco
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Your new plant or expansion idea

Raw materials available?

Market available?

Location correct?

Capacity adequate?

Readily financed?

Right time to build?

Kaiser Engineers specializes in the design and construction of major facilities used throughout the Minerals industry, and has world-wide experience in design of such facilities.

Among KE's most valued services are sound, searching, economic analyses, feasibility studies and site and market evaluations. In a word—*Pre-Engineering*—impartial, outside analysis which helps you decide whether to proceed with, defer or modify the project.

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8459-M

type TY
GYRATORY CRUSHER

Traylor-made
for uniform secondary reduction

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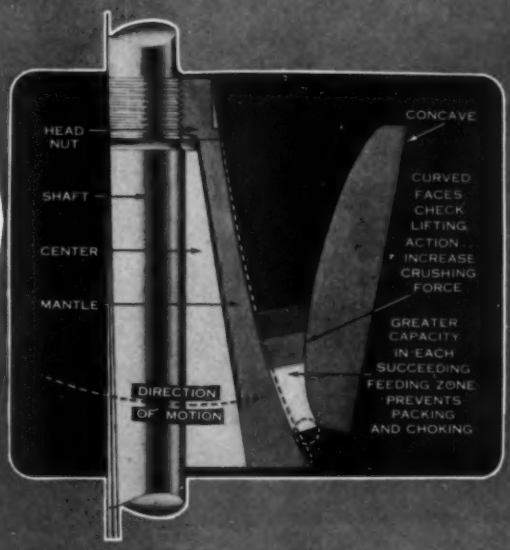

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5469-M

SHATTUCK DENN

offsets rising costs with improved Cyanamid Reagent Combinations

At its Humboldt, Arizona Iron King Mill, Shattuck Denn Mining Corporation treats 1000 tpd of a complex, fine-grained sulfide ore by flotation and cyanidation to recover lead, zinc, gold and silver plus a small amount of copper. While this is primarily a lead-zinc operation, recovery of gold occurring in the pyrite and silver occurring in tennantite is important to profitable operation. Heads average about 50% pyrite, and contain 8-9% Zn, 2.5-3% Pb, in addition to gold and silver values.

In 1942 Shattuck Denn evolved an "index of economic recovery" for evaluating daily metallurgical results from five pay metals recovered with two differential flotation operations and subsequent cyanidation of the flotation tails with AERO® Brand Cyanide. The index compares actual returns with the theoretical maximum dollar return based on current metal prices, freight and treatment charges.

Rising costs have compelled constant study and revision of reagent combinations. But, because of improved metallurgy and milling equipment, zinc economic return now exceeds the theoretical maximum economic recovery. Recently, reagent changes again improved metallurgy and dollar return, as reported by the Cyanamid Field Engineer working on the job with Shattuck-Denn metallurgists:

"SODIUM AEROFLOAT® Promoter has replaced potassium ethyl xanthate in the zinc circuit. AEROFLOAT® 208 Promoter, AERO® Xanthate 301 and AERO® Depressant 620 have replaced AERO® Promoter 404 and potassium ethyl xanthate in the lead circuit."

"As a result, the economic recovery index for the first six months of 1959 is 12.3% better than the figure for the year 1956. Particularly noteworthy is a 26% increase in economic recovery in the zinc circuit, due primarily to the use of SODIUM AEROFLOAT Promoter. Reagent changes in the lead circuit have also improved lead concentrate grade and lead recovery."

An important part of the extra value received by users and prospective users of Cyanamid reagents are the services of Cyanamid Field Engineers backed by the Cyanamid Mining Chemicals Laboratory. The nearest Cyanamid Field Engineer will be glad to work with you in using Cyanamid reagents to help you try to cut costs and improve metallurgy.

REAGENTS, LB/TON, PRESENT

Ball Mill		Pb Circuit		Zn Circuit	
AERO Brand Cyanide	0.73	AERO Xanthate 301	0.05	CaO	2.2
$ZnSO_4$	0.88	Cresylic Acid	0.01	$CuSO_4$	2.1
AEROFLOAT 208	0.05	AERO Depressant 630	0.015	SODIUM AEROFLOAT	0.18
				Cresylic Acid	0.02

REAGENTS, LB/TON, PREVIOUS

Ball Mill		Pb Circuit		Zn Circuit	
AERO Brand Cyanide	0.52	K Ethyl Xanthate	0.02	CaO	2.3
$ZnSO_4$	0.79	Cresylic Acid	0.05	$CuSO_4$	2.4
AERO Promoter 404	0.04	Methyl Isobutyl Carbinol	0.04	K Ethyl Xanthate	0.25
				Cresylic Acid	0.01

RESULTS

	Present, 6 mos. 1959	Previous Year 1956
Overall Economic Recovery	83	70.7
Zinc Economic Recovery	100	74
Pb Concentrate, % Pb	32.8	26.4
Zn Concentrate, % Zn	56.3	50.4

AMERICAN CYANAMID COMPANY

EXPLOSIVES AND MINING CHEMICALS DEPARTMENT

CYANAMID

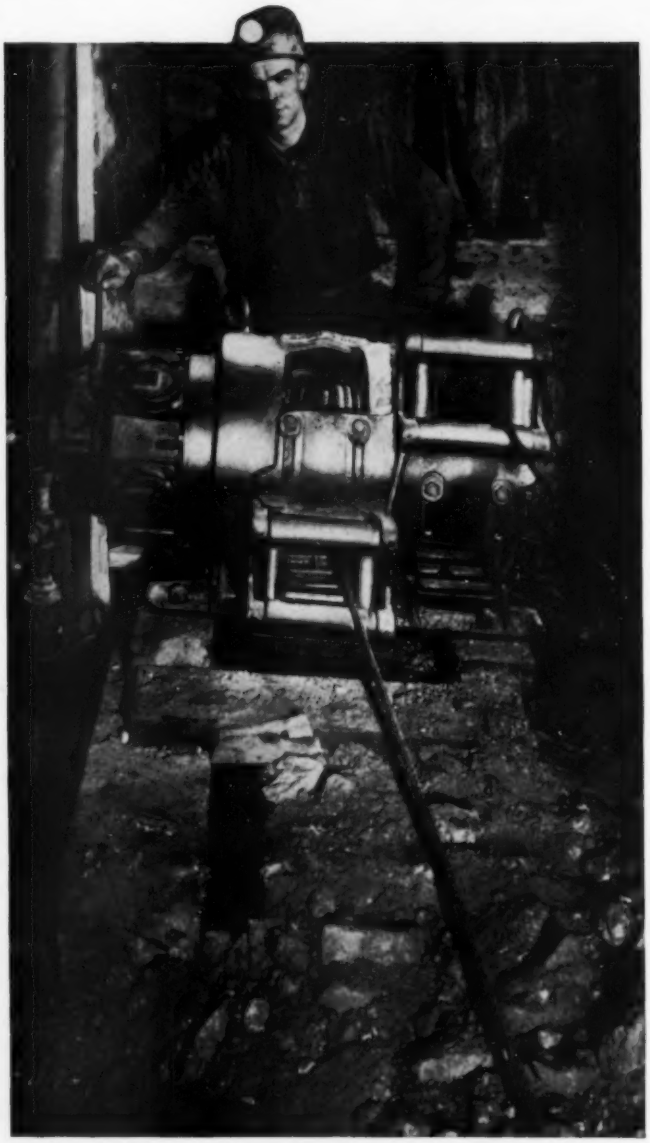
CYANAMID INTERNATIONAL—*Mining Chemicals Department*
Cable Address:—Cyanamid, New York

30 ROCKEFELLER PLAZA, NEW YORK 20, N. Y.

MOVE MORE ORE WITH GARDNER-DENVER "AIRSLUSHERS"

. . . power for a full scraper every trip

. . . speed for faster round trips



Plenty of slushing power—high-torque, 5-cylinder radial air motor provides digging and tugging power to fill scraper on every pass.
Easy to operate—single lever controls power in either direction. When lever is released, air motor stops—does not waste air idling.
Stays underground—air motor and drive are completely enclosed to keep water and dirt out . . . oil in. Parts are designed to deliver maximum service with little maintenance.
No clutch facings to wear—simple roller clutch automatically and instantaneously engages one drum and releases the other as throttle is reversed.
Only three points to oil—air motor, gear train and throttle valve.

Move more muck with the finest of slusher hoists—Gardner-Denver "Airslushers." Write for details.

CALL THE GARDNER-DENVER MAN

Your Gardner-Denver mining equipment specialist is trained to assist in drilling and mucking problems . . . to help keep your Gardner-Denver equipment in tiptop shape. At Gardner-Denver *there's no substitute for men*—our 100-year philosophy of growth.

EQUIPMENT TODAY FOR THE CHALLENGE OF TOMORROW

GARDNER-DENVER

Gardner-Denver Company, Quincy, Illinois
Export Division, 233 Broadway, New York 7, New York
In Canada: Gardner-Denver Company (Canada), Ltd., 14 Curity Avenue, Toronto 16, Ontario

REPLACEMENT OF CAPITAL EQUIPMENT

What happens when a piece of capital equipment must be replaced and there is no systematic method of selection? Answer: Generally, hurry-up purchase of equipment which may later be found unsuitable. Here is how New York Trap Rock efficiently schedules its replacements.

by **HENRY J. SCHWELLENBACH**

Lack of a system in scheduling the replacement of capital equipment can result in emergency purchases of units which may later be found unsuitable for the job. New York Trap Rock Corp., which produces crushed stone for use as construction aggregate, was faced with just such a situation some years ago. The company replaced capital equipment only when machinery in use was no longer serviceable, or when there was an obvious need for different equipment. Operating and maintenance costs were generally neglected because an efficient method was lacking.

New York Trap Rock has four plants located along the Hudson River, all within 70 miles of New York City. Crushed stone output—6 million tons a year—is moved to markets in metropolitan New York, New Jersey, and Long Island areas by water transport. Customers are contractors with ready-mix concrete and asphalt plants located on the water.

A few years ago, when it became apparent that a systematic method of capital equipment replacement was needed, the company began to evaluate several systems. An individualized plan was evolved from the basic pattern developed by the Machinery and Allied Products Institute.

The system is as satisfactory as it is simple. When anyone suggests that a machine or method requires replacement or change, a committee composed of the production manager, maintenance supervisor, and chief engineer determines the particular type of equipment best suited for the job. The purchasing department is then requested to contact suppliers for consultation and quotations.

Using these quotations as a basis, a detailed analysis is made. If the financial return is too low, the committee will concentrate on the merits of a substitute solution, whether it be some other piece of equipment or alteration of present equipment. If the analysis shows a high enough financial return, a request to purchase the equipment is submitted to the expenditures committee.

Basically, the Machinery and Allied Products Institute formula makes a comparison between the next year's estimated operating costs of present equipment and the estimated operating cost of proposed equipment. To this analysis is then added the difference between the costs of continuing owner-

H. J. SCHWELLENBACH is Production Manager, New York Trap Rock Corp., West Nyack, N. Y.

EQUIPMENT OR METHOD ANALYSIS

1. Plant **Haverstraw** Project No. **P-65** Analysis No. **H-2** Date **July 1957**
2. Subject of Analysis **Electric Shovel** Date of Preliminary Request **August 2, 1957**

	PRESENT EQUIPMENT	PROPOSED EQUIPMENT
3.	Description **4-cu yd electric shovel**	Description **5-cu yd electric shovel**
4.	P.O. No. **H-628**	Source ———
5.	Salvage Value **$2,000** Salvage Ratio **.033**	Cost of Unit **$200,235** Cost of Installation **$17,152**
		Cost of Unit ——— Cost of Installation ———
6.		Cost of Unit ——— Cost of Installation ———
		Total Installed Cost **$217,387**

NEXT YEAR'S OPERATIONAL DIFFERENCES	PRESENT EQUIPMENT Amount	PRESENT EQUIPMENT Advantage	PROPOSED EQUIPMENT Amount	PROPOSED EQUIPMENT Advantage
7. Increased production @ 80¢ per unit	———	———	120 yd per hr	$201,600
8. Operating labor	$30,225	———	$30,225	———
9. Operating supplies (except fuel or power)	300	———	300	———
10. Fuel or electric power	4,560	$2,210	6,770	———
11. Maintenance labor	6,000	———	1,000	5,000
12. Maintenance supplies	10,000	———	2,000	8,000
13. Fringe benefits 20 pct of (8 + 11)	7,200	———	6,200	1,000
14. Special repairs	———	———	———	———
15. Other (explain—other side)	———	———	———	———
16. TOTALS	———	2,210	———	215,600

PRESENT EQUIPMENT		PROPOSED EQUIPMENT	
17. Next year's salvage loss	———	26. Installed cost	$217,387
18. Interest @ 10 pct x salvage value	$200	27. Estimated service life	25 years
19. Restorative repairs	50,000	28. Estimated salvage value	$3,200
20. Years effective	10	29. Salvage ratio (line 28 ÷ line 26)	.014
21. Next year's proration	5,000	30. MAPI chart	5.5%
22. Interest @ 10 pct x line 19	5,000	31. Interest	10%
23. Next year's capital cost	10,200	32. Total percent x installed cost (Next year's capital cost)	$33,695
24. Next year's operating disadvantage (line 16)	213,390		
25. TOTAL	$223,590		

33. Next year's gain from replacement **$189,895** Calc. by **J. B.** Appr. by **J. B. K.**

Trap Rock's forms for replacement analysis and periodic appraisal of new equipment in use

ANNUAL FOLLOW UP—CAPITAL EXPENDITURE*

Plant **Haverstraw** Project No. **P-65** Analysis No. **H-2**
Brief description of project; **Replacement of 4-cu yd electric shovel with a 5-cu yd machine**
Purchase order **H-1842** Date Installed **October 1957** Work order **5-65**

	Analysis Factors Estimated	Actual	Variation
Operating labor	$30,225	$24,510	$5,715
Maintenance labor	1,000	4,021	3,021
Fringe benefits @ 20 pct	6,245	5,707	538
Operating supplies	300	213	87
Fuel or electric power	6,770	4,035	2,735
Maintenance supplies	2,000	3,913	1,913
Special repairs			
Total operating cost	46,540	42,399	4,141
Increased production @ .80 per unit	201,600	142,032	59,568
Operating hours	2,100	1,614	486
Units produced or handled	672,000 yd	500,016 yd	171,984 yd

	Estimated	Actual	Variation
Installed cost	217,387	222,733	5,346
The year's operating advantage	213,390	151,591	61,899
The year's capital cost	33,695	34,525	830
Gain from replacement	189,895	127,266	62,629

General comments: **New machine averaged 310 yd per hr compared to estimate of 320 yd per hr. Build-up of two buckets and trials of new type dipper teeth account for higher maintenance cost. Decrease in hours due to reduced production demand.**
Prepared by: **J. B.** Date **December 16, 1958**

* To be submitted first & second year after installation.

ship of existing equipment and of acquiring proposed equipment. For present equipment, consideration is given such items as restorative repairs, salvage value, salvage-value loss, and interest or cost of money. For proposed equipment, the concentration is on actual depreciation (as opposed to either book or tax depreciation), cost of money, and anticipated salvage value.

An explanation of the theory used in the Machinery and Allied Products Institute method of analysis can be found in the reference material and will be omitted here. The following details New York Trap Rock's use of the forms and shows the results obtained.

The accompanying copy of the analysis form used by the company is a typical analysis of an electric shovel replacement.

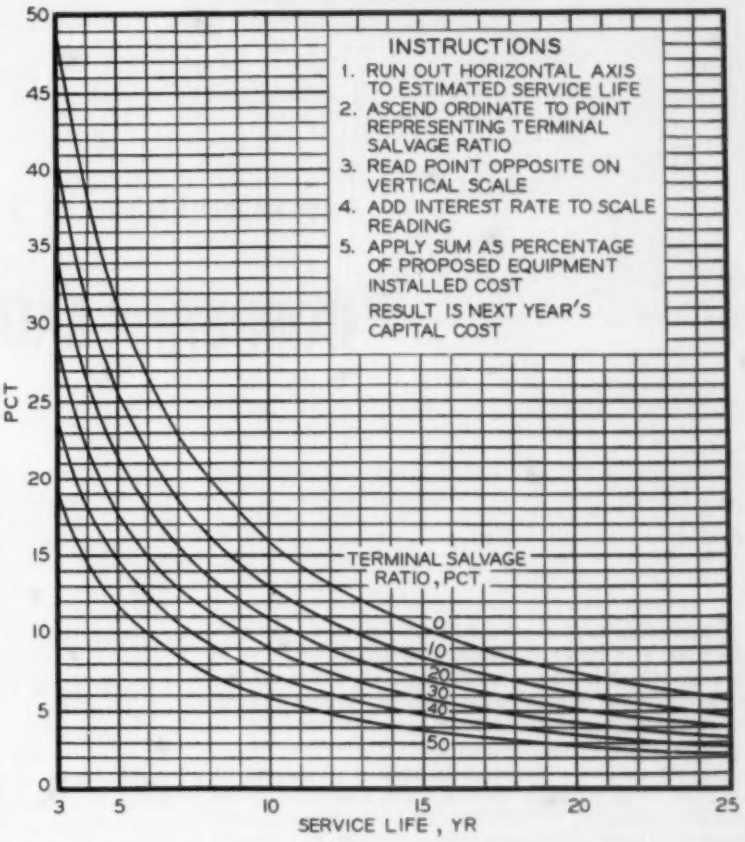
The title portion of the form is important for future reference and record keeping. Descriptions of present equipment and proposed equipment can be as complete as necessary. Salvage value of present equipment is usually estimated. Salvage ratio is the salvage value divided by the original installed cost. For proposed equipment the total purchase price of the equipment and its installation cost make up the total installed cost.

The second part of the analysis shows the next year's operational differences between the present and proposed equipment. This compares all operating and maintenance costs and indicates the financial advantage of either the present or proposed equipment. The value of any increase or decrease in production should also be included in this calculation. Total advantage of proposed equipment minus total advantage of present equipment represents the operating disadvantage of retaining the present equipment next year. If this proves to be a negative figure the analysis should stop at this point unless other factors must be considered.

The third part of the analysis calls for calculation of the total cost of operating the present equipment for the next year if the equipment is not replaced. Included are: the difference between present salvage value and salvage value one year later; the amount of interest that could be earned on money realized from sale of the equipment if restorative repairs are necessary; and, the interest on that money, as well as the amortization of the principal, for the first year. The total of these amounts, together with the next year's operating disadvantage of the equipment, represents the potential cost of retaining and using this equipment.

The fourth part of the analysis form requires calculating the next year's cost of owning the proposed equipment. The estimated salvage value divided by the installed cost gives the salvage ratio for the new equipment.

CHART FOR DERIVING NEXT YEAR'S CAPITAL COST FOR PROPOSED EQUIPMENT BY THE MAPI FORMULA



Using a chart which is a graphic approximation of the formula developed by the Machinery and Allied Products Institute (see illustration), a percentage figure is obtained. This figure, together with the interest rate used by the company for the cost of money, is applied against the installed cost of the proposed equipment. The result is the next year's cost of ownership of the proposed equipment.

The difference between the potential cost of retaining and using the present equipment and the next year's cost of ownership of the proposed equipment is the next year's gain from replacement. This gain in relation to the installed cost indicates to the expenditures committee the priority of the approved expenditure.

At regular intervals, follow-up analyses are made to compare actual operating and capital costs with the estimates used in the original analysis. The first annual follow-up sheet for the shovel replacement is also shown in an accompanying illustration.

While there are many viewpoints on the matter of equipment replacement, New York Trap Rock feels the adopted approach evaluates all the factors necessary for sound decisions.

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Paley Report Series—No. 3

COPPER, LEAD, AND ZINC—

Another analysis of the forecasts made by the President's Materials Policy Commission in 1952.

Attempting to analyze a 25-year forecast after less than a third of the time has elapsed may seem premature. The President's Materials Policy Commission's report necessarily painted with a broad brush and made no claim for pinpoint accuracy in its predictions. More importantly for present purposes, it made no attempt to predict the detailed courses of production and consumption during the period forecasted. Several statistical highs and lows may very well lie between now and 1957, so comparing recent figures with points taken from the report on a straight-line basis would be illogical. Moreover, the report assumed that the general trend of consumption—domestic and foreign—would be upward. Contrarily, domestic figures were lower in 1957 than in 1950. Therefore, to project curves from 1950 through 1957 leads to conclusions that are probably false. Many in the industry would feel more uncertain about forecasting 1975 domestic conditions now than they would have been in 1950, even though nearly a third of the 25 years has elapsed.

In making comparisons, several statistical problems are encountered. The Paley report figures for 1950 were estimated in several cases and corrected figures vary as much as 10 pct. For example, the report placed 1950 lead consumption at 800,000 tons, whereas actual consumption was 885,000 tons. Obviously, in comparing more recent figures with the report's projections, adjustments must be made for positions taken in error from the start. Over the long pull, such discrepancies will probably be insignificant, but they must be noted in comparing short-term changes.

Domestic metal consumption in 1957 dropped sharply from the peak year 1955. On the other hand, Free World consumption outside the U. S. was upward, both from 1950 and from 1955 to 1957. To obtain projections that partly modify the 1957 extremes, the accompanying table projects from 1950—through mean averages of 1955 to 1957—into 1957. These projections are compared percentage-wise with adjusted PMPC projections.

From the table it may be seen that the PMPC report overrated U. S. consumption and greatly underrated consumption elsewhere in the Free World. Because these two areas moved in opposite directions, the error is less for the Free World as a whole. Again, making comparisons with straight-line interpolations of the PMPC figures is not logical. However, if we can presume that the recent depressed domestic consumption is abnormal, we can deduce that total Free-World consumption is likely to exceed the estimates of the PMPC report. Lead may be an exception.

As for domestic production, copper output has climbed higher than the report anticipated. The expected decline in lead production to 350,000 tons was realized in 1957, but this sharp decline was due to recession conditions. Some increase in zinc production was expected. An upward trend did exist in the first three years, but low prices from world overproduction and recession conditions in 1957 brought production well below that of 1950.

The Paley report depicted copper, lead, and zinc as metals that would continue to be scarce. Broad substitutions were therefore anticipated for copper and zinc. Less substitution was expected for lead on the grounds that it had already been reduced to its more essential use. But instead of scarcity we have overabundance, low prices, and cutbacks in production.

The report itself contributed importantly toward the present abundance. The adverse attitude to the report so evident among nonferrous mining men did not prevent them from using the report's general portrayal of impending scarcity to justify large expenditures for development of new mines. Expansions thus justified, and supported by easy credit from Government agencies, have had much to do with the present abundance. High metal prices in the early 50s also encouraged expansion, but the PMPC report helped create the attitudes that pushed prices to these levels.

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PREDICTIONS AND EXPERIENCE

by EVAN JUST

The next 25 or even 50 years will probably demonstrate that the word scarcity was unrealistic. As the better mines are depleted, prices will rise, unless improved methods reduce costs or substitutions are made. Scarcity will not be evident until consumers cannot find effective substitutes. It is very difficult to say what price consumers will pay for things they must have. Also, substitutes for copper, lead, and zinc in all present major uses are already available, at moderate increases in cost. Lead in storage batteries is probably the most difficult metal to replace, nickel and cadmium being less abundant than lead. However, battery use permits almost complete lead reclamation. Lead, cadmium, or nickel prices of even $10 per lb would not drive storage batteries out of common use, if an effective substitute could not be found.

In terms of present concepts, the Paley report overdrew the raw-material needs of wartime by embracing the traditional idea that war would greatly increase requirements. It now appears that major war, if it occurs, will destroy consuming capacity more than raw-material production. War would thus tend to create oversupplies of raw material by greatly shrinking markets. The wreckage of cities would also provide large quantities of scrap metal. The failure to anticipate this new military outlook was universal during the early 50s, so the PMPC can hardly be criticized on this count.

The commission was correct in anticipating continued drives for price and market stabilization. It perceived that tariff increases were unsuitable to the U. S. both in its position as a large importer and to its status as leader of the Free World. Domestic nonferrous metal producers took an opposite view, sponsoring tariff increases. This position proved to be anachronistic when Congress scuttled tariff increases for lead and zinc despite Administration and Tariff Commission endorsement. The PMPC recommended stabilization measures through international agreement, possibly supplemented by buffer stocks. Recent history suggests that sooner or later commodity markets will be stabilized through international agreements. The sources of market volatility in copper, lead, and zinc are international. Any unilateral attempt to control markets not only fails to reach the sources of trouble but offends nations whose raw materials and good will the U. S. cannot afford to lose. Although the U. S. recently set up quotas on lead and zinc, this was done under extreme political pressure during an election campaign and in expectation that an international accord would be reached. If no such agreement is obtainable, the feasibility of the unilateral quota arrangement is questionable.

Abundance and reduced consumption of copper, lead, and zinc in depressed years tend to put the forecasts of the PMPC in a bad light, but if we were riding a boom, we would probably find the report defective for opposite reasons. On balance, the commission probably underrated the economic growth of the Free World and overdrew the bogie of scarcity.

U. S. and Free World Consumption of Copper, Lead, and Zinc, 1950 to 1957

Consumption	1950	1955	1957	1955 to 1957 Mean	Projected 1957	Adjusted PMPC	Error, Pct
Copper, Thousands of Pounds							
U.S., Primary	1254	1290	1170	1230	1238	1390	14
Free World, Primary, except U.S.	1300	1620	2090	1850	1940	1500	−22
Free-World Total	2554	2910	3260	3080	3190	2890	−9
Lead, Thousands of Pounds							
U.S., Primary	885	810	703	756	725	998	38
Free World, Primary, except U.S.	894	1171	1216	1193	1230	1076	−13
Free-World Total	1779	1981	1919	1949	1955	2074	6
Zinc, Thousands of Pounds							
U.S., Primary	967	1120	924	1022	1031	1079	4
Free World, Primary, except U.S.	980	1362	1424	1393	1462	1278	−13
Free-World Total	1947	2482	2348	2415	2493	2357	−5

by L. O. MILLARD

STOCKPILING

- PURPOSES
- METHODS
- TOOLS

Stockpiling is important to all segments of our economy, but it is a term that means many things to many people. To industry it means piles for reserve supply over the winter, insurance against strikes and shipping delays, use as surge at various production stages, or inventory of finished products.

Stockpiles in the minerals industries serve a wide variety of purposes. Usually they are for surge between stages of processing, for a dependable plant feed in anticipation of delays, or to provide for single or double shift mining in conjunction with round-the-clock milling. Often surge piles are necessary to insure a uniform feed to continuous process equipment where the material is received as an intermittent or variable flow.

Extensive use is made of stockpiling for the primary purpose of blending.

The significant fact about all stockpiling of bulk materials is that storing and reclaiming are two separate and distinct operations and they may present widely different problems in the selection of methods and tools.

Among the most important factors affecting selection of methods and tools are: a) the material to be stored, b) the quantity required in the stockpile, c) the height of pile, d) the time in storage, e) the rate of turnover, f) the rates at which material is stored and reclaimed, and g) the influence of climate and weather.

Materials to be Stored: The physical and chemical characteristics of the materials have a dominant influence on design. Size and percentage of lumps often determine the type and size of equipment and feed openings, regardless of capacity requirements. Segregation increases for wider size ranges and with the height of pile. Other inherent characteristics, such as weight and abrasiveness, affect design and maintenance costs of equipment.

The flowability of materials or their resistance to flow due to sluggishness or packing are often unimportant in storing, but usually determine the basic method of reclaiming. Free flowing materials may be reclaimed economically at all capacities by means of gates and relatively simple feeders to tunnel belt conveyors. Sluggish materials may require more expensive feeders and tunnel construction, or may not be suited to tunnel reclaiming. In extreme cases it may be necessary to practically remine them from the stockpile.

The angle of repose of the material as it is piled influences the area required. For tunnel reclaiming methods, on the other hand, the amount of live storage is governed by the angle of repose as material is withdrawn, which may be quite different from the storing angle. Also, when shovels are used for reclaiming, the reclaiming angle may limit the height of pile as a safety precaution against avalanching slides.

Size degradation occurs to some extent to all materials as they are stored and reclaimed. Where the value or usefulness of a product is reduced by excessive degradation, intriguing design problems are involved in reducing drop and impact at transfer.

Materials affected by time, climate, or weather must receive particularly careful consideration.

Dust may be objectionable in some localities, and wind and erosion can result in substantial losses.

Quantity to be Stored: The quantity to be stored must be calculated by a careful analysis of all factors. Where ample space is available, piles can be arranged for most economical use of equipment. Where the area is limited, its size and shape and the resulting height of the pile will influence equipment selection.

When material is to be reclaimed through tunnels, it is necessary to consider the percentages of live and dead storage, as well as the method, frequency, and cost of reclaiming dead storage.

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Height of Pile: Height provides an obvious means for increasing tonnage in stockpiles with relatively broad bases. However, height is often limited by soil conditions, nearness to a dock, characteristics of the material, and, occasionally, cost and power required for the equipment. Danger of slides must also be considered when using shovels.

Time in Storage: Prolonged time in storage may cause spontaneous combustion, wind or erosion losses, freezing, packing, cementing, and leaching or other chemical deterioration.

In some surge piles, storing and reclaiming may occur simultaneously most of the time. A stockpile which serves as insurance against strikes or transportation delays may remain with few major fluctuations for months—possibly part of it for years. When piles are turned over continuously or frequently, high equipment cost can usually be justified to produce lower operating cost and dependability. Where turnover of large stockpiles is infrequent, it is often more economical to keep capital cost of equipment low, even though costs are high during the brief periods when material is being handled.

Rates of Storing and Reclaiming: These rates depend upon the purpose and economics of the operation. To assure minimum dock time of large, expensive vessels, they must be loaded and unloaded at extremely high rates. Surge piles for sustaining these rates are built up or reclaimed at much lower rates.

Stockpiling can cut transportation costs when materials are received intermittently—from railroad cars or from trucks operating only one shift a day—but consumed or processed continuously. By contrast, some plant surge piles may be stored and reclaimed at virtually the same rate, with the pile providing a balance between the two operations.

Effect of Weather: Effects of weather on the material may include freezing, packing, hardening, leaching, dust losses, or erosion of the pile. All of these require careful consideration of material characteristics, seasons, time required to store and reclaim, and maximum time in storage.

Methods and tools for both storing and reclaiming depend upon weather, but for reclaiming both are also influenced by the condition of the material when it is to be used. It may be necessary to shoot or rip crusts of frozen material and crush the frozen lumps. Materials that are packed hard or cemented may also present problems of extraction.

The influence of these basic factors in various combinations as they affect the methods and equipment of stockpiling can best be illustrated by considering a few existing installations.

At this public utility power plant, coal is received during the Great Lakes navigation season either in self-unloading boats or conventional bulk carrier vessels. The stockpile must contain enough coal for the four or five months that lake navigation is closed and also hold a reserve for possible strikes and transportation delays. It also provides surge between vessel arrivals.

Self-unloading boats discharge at 1800 tph into a stationary hopper on the dock. Bulk vessels are unloaded by a grab bucket tower at 1200 tph. In either case, coal is conveyed to a traveling belt conveyor stacker with a boom long enough to deliver the coal to a narrow initial surge pile parallel with the main conveyor. From this surge pile, conventional earthmoving equipment distributes it to a

large reserve storage pile as convenient. At the same time, the coal is layered and compacted to reduce the hazard of spontaneous combustion. The flow of coal may be split in the stacker and part of it then proceeds to the crushing station and plant.

Reclaiming may be accomplished by either or both of two methods. A grab bucket tower, traveling on the stacker tracks, is available for reclaiming 600 tph to the main belt. Also, a ground level reclaiming hopper at the inshore end of the pile is equipped with a feeder and belt conveyor for moving 600 tph to the crushing station. In both cases, earthmoving equipment is used to dig and transport the coal to surge piles above the hopper and within reach of the grab-bucket tower.

Although substantial investment in unloading and conveying equipment was necessary for the high unloading rates, added capital cost for stockpiling equipment is relatively low. Both expenditures are justified by the lower cost of water-borne coal, the need for a dependable fuel reserve, and anticipated expansion.

At this St. Lawrence River plant, where titanium ore is concentrated, treated and smelted, seasonal water transportation requires extensive stockpiling of ore and coal for consumption during the winter when the river is closed. Both materials are unloaded from ships and are conveyed to the plant, or to their respective stockpiles by the same belt conveyor system. In each case the material is delivered by a short-boom stacker to surge piles along the

Fine, free-flowing smelter product is protected from weather by stockpiling in large building shown at upper right center. Reclaiming is done by tunnel feeders and conveyor system.

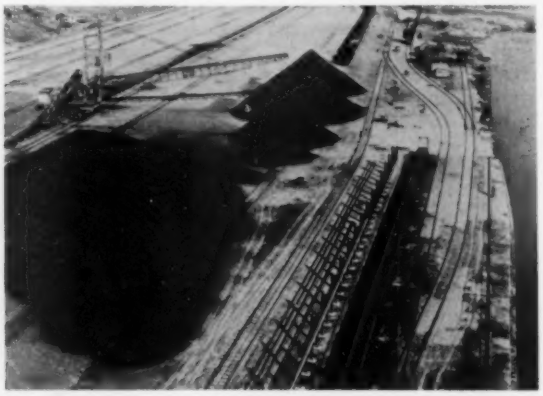
main conveyor. From the piles it is recast to stockpile with a crawler-mounted grab-bucket crane. Dozers assist in distribution, but it is not necessary to carefully layer and compact the coal due to its analysis and the relatively brief storage period.

Reclaiming during the rigorous winters is difficult and requires considerable overtime, but these peak operating costs are justified.

Cost of unloading equipment was high due to the required unloading rate, but the added capital cost of stockpiling equipment is relatively low.

This Canadian coal dock's stockpiles are built up at the rate of 650 tph by a belt conveyor stacker which travels the length of the 1720-ft belt conveyor. It is equipped with a 150-ft-radius, hinged rotating boom belt which enables it to discharge to either side of the conveyor.

The hinged boom belt may be lowered as a means of reducing *degradation*. *Segregation* is greatly minimized by depositing the coal in shallow windrows. A high degree of blending can be accomplished by bedding these shallow windrows from one end of the pile to the other as the stacker travels.

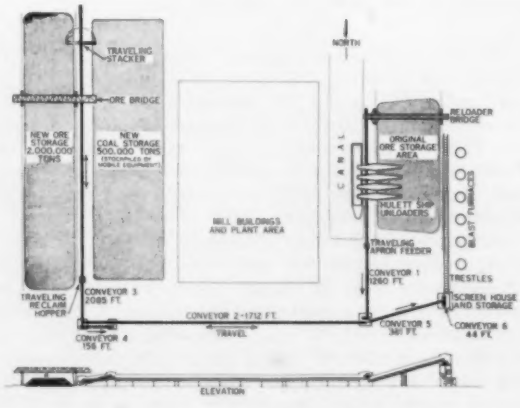


An extremely flexible system for stockpiling and blending as many as four different grades is found at this Utah iron ore mine. Ore is dumped by trucks at the crusher house, from which it is conveyed to the screening tower at the rate of 1000 tph. From this tower one size can be conveyed directly to the carloading pocket, or all sizes may be stockpiled by two distributing conveyors and their belt conveyor stackers.

Since the ore is relatively dry and free-flowing, it is reclaimed to the tunnel reclaiming belts at up to 1500 tph by variable-speed, traveling, reciprocating feeders below the tunnel gates.

Storage space for raw materials at a large Eastern steel mill was formerly limited to a stockyard between blast furnaces and a dock beside the ship canal. With greatly expanded operations and an increased variety of iron-bearing burden materials, the area became totally inadequate for containing reserves during the winter period when the canal was closed to navigation.

Their problem was solved by stockpiling on a greatly increased scale in an available space beyond the mill area. Ore, pellets, or limestone from the vessels may now be unloaded directly into the old stockyard or conveyed at 6000 tph either to the screenhouse ahead of blast furnace stock bins, or transported to the new storage area over a belt conveyor system at 6000 tph. As needed, they are returned to the screening plant over the same system. Coal is conveyed directly to the new stockpile area.



The original blast furnace stockyard was confined between the bridge runways. With the new system, ore is unloaded from the ships to the belt conveyor at dockside, or coal may be delivered directly from the booms of self-unloading boats to the traveling receiving hopper shown above the conveyor in the left center of the photo at right.

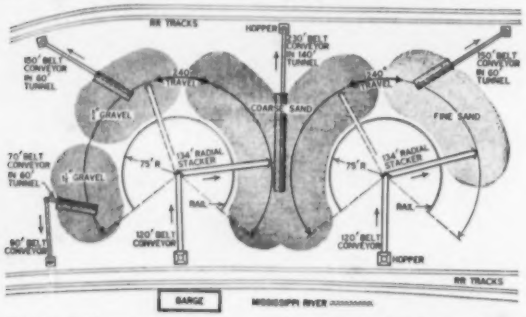
In the new stockpiling area, materials are discharged from the belt conveyor by means of a traveling stacker which builds an initial surge pile of coal (see photo below), from which it is distributed to the principal stockpile by mobile earthmoving equipment. Pellets, iron ore, or limestone may also be deposited in a similar surge pile (on left) for recasting by the bucket type bridge.

The ore, pellets, and limestone are also reclaimed by the bridge to a traveling hopper and feeder to the same belt conveyor of 2100 ft centers and returned to the screening plant. The coal is reclaimed by earthmovers and conveyed to the coke plant on another belt conveyor system.

The shipping season is a primary consideration at this Lake Superior dock where commercial coal is received in Great Lakes vessels during the summer, and reclaimed and trans-shipped largely during the winter. A few years ago two very old traveling bucket bridges were equipped with belt conveyors to provide for broad, economical distribution to stockpiles. Coal is unloaded by bucket unloaders and conveyed by a main-line conveyor serving either bridge. In this case, size degradation of the coal is not important.

The coal is reclaimed by the existing bridge buckets, at lower rates, intermittently as needed.

The arrangement illustrated is characteristic of aggregates plants which must stockpile great quantities and varieties of finished inventory. In the case



of this Minnesota yard, washed and sized sand and gravel are delivered by river barge. Radial stackers, useful tools for stockpiling, are employed.

This particular stacker is equipped with a 24-in. wide belt with 143 ft centers. It represents relatively low capital cost for the amount of material placed in storage. Since each of the two stackers at this in-

stallation swings in a 240° arc, the stockpile is many times larger than can be produced by a stationary stacker of the same size. Similar units have been used on a substantially larger scale, and the receiving ends of some are mounted on tall sub-structures when a high pile is not objectionable.

Due to the free-flowing characteristics of sized aggregates, they may be reclaimed to belt conveyors

by means of simple gates through low cost tunnel structures without the use of feeders.

Copper ore from a western mine is handled at the rate of 26,000 tpd by a series of belt conveyors. The ore is stored in a 35,000-ton stockpile or in a 5000-ton ore bin from which the ore is loaded into railroad cars. This system is extremely flexible, permitting mine ore to be discharged into open stockpile or to be transferred by shuttle belt conveyor to a horizontal belt conveyor leading in turn to the conveyor which travels over the ore bins. Four heavy-duty apron feeders beneath the storage pile reclaim to an inclined belt which also carries the ore to the conveyor above the ore bin. This conveyor, which is equipped with a self-propelled traveling tripper, can receive from both conveyors simultaneously.

The bins are arranged for loading ore out on two tracks at the same time.

Iron ore is stockpiled on a tremendous scale at one Venezuelan port to provide a surge between railroad cars from the mine and shiploading. The port

is 178 miles up the Orinoco River, and the mine is another 90 miles inland. It loads the world's largest dry cargo vessels—up to 60,000 tons dead weight. Ore from the cars is dumped in a rotary dumper at the rate of 67 cars per hr. After primary and secondary crushing, it is conveyed to storage and discharged onto an 80-ft-high storage pile by a belt conveyor tripper on a traveling bridge with 400-ft span. The ore is reclaimed from stockpile at the rate of 6000 tph by four rotary plow feeders in two tunnels beneath the stockpile. The ships are loaded by a self-propelled traveling shiploader designed to handle both large and small ocean vessels at any time of the year, despite an annual 39-ft rise and fall of river level.

During early stages of this operation, sufficient surge was available by withdrawing live storage from the pile without depending on auxiliary means for reclaiming dead storage—of which there remained a high percentage. When the shipping rate increased beyond 12 to 15 million tons annually, additional useable surge was made available by two improvements.

1) A traveling drag scraper was installed to recast dead storage over the tunnels so that the ore could be reclaimed by the tunnel's rotary feeders at the 6000-tph rate. The scraper has its traveling towers mounted on separate rails outside the bridge rails.

Effectiveness of the rotary plow feeders is shown in this aerial view taken when equipment was first installed.

View within reclaiming tunnel shows ore settled on shelf. Note traveling rotary plow feeder and the reclaim belt.

2) The pile was extended to provide more overall surge capacity, and the dock was extended to dispatch vessels more rapidly.

The rotary blades of the tunnel feeder plow the ore from a horizontal shelf beneath the trough through a feed opening which runs the full length of the tunnel. The feeder travels back and forth, plowing ore from the shelf onto a transfer belt conveyor which also travels through the tunnel. A reclaim belt conveyor carries the iron ore from each tunnel, transferring it onto the main belt conveyor leading to the dock.

The rotary plow feeder has a number of advantages over other devices for withdrawing materials with a tendency to pack and arch over rectangular openings. The feed opening is continuous for the entire length of the tunnel, offering less support for arching than rectangular feed openings. Arch support is largely undercut by rotating blades, as the entire feeder travels beneath material that has arched solidly above the cutting range of the rotor blades. Each feeder is interlocked with the master control of the reclaiming system, and its functions are controlled by the shiploader operator.

In Northern Minnesota where the temperature sometimes drops to—45°F and the winds sometimes exceed 100 mph, one company has an enormous stockpiling system required for winter storage of taconite pellets. The pellets are produced in a pelletizing plant near the orebody, and then shipped by rail 74 miles to a port on Lake Superior. The plant operates 24 hr a day, 12 months a year, but pellets can be shipped to the harbor only during the Great Lakes navigation season—about seven months a year.

In the summer, taconite pellets are conveyed from the pelletizing plant to the 800-ton surge bin of a car pocket. During normal operation, the car pocket is designed to load 85-gross-ton cars on one track at full plant capacity. When more pellets are

delivered than the surge bin can handle the flow can be diverted to an emergency belt conveyor which conveys the pellets to a temporary stockpile of about 13,000 tons.

In the winter, when all plant production must be stockpiled, the car pocket is bypassed. Flow from plant conveyors is routed to a large traveling stacker via a cross conveyor and trailing conveyor.

This unit is believed to be the world's largest traveling belt conveyor stacker. It has a 275-ft radius boom. Overall length, from tip of belt boom to end of counterweight boom, is 416 ft. The stacker will build a stockpile 90 ft high, and more than 4 million tons of pellets will be stored in an area 800 ft wide at the base and 1300 ft long.

The stacker is mounted in eight four-wheel trucks which move over a pair of 6-ft gage ballasted sectional tracks on 60-ft centers. The trailing conveyor, on about 1400-ft centers, is moved by a draw bar from the stacker under-carriage, advancing and retreating with the stacker.

The stacker moves out to a point where discharge from the boom is at the edge limits of the storage yard. The boom builds the pile to its maximum height and slowly retreats, describing an arc as it beds the material in windrows. The stacker retreats about 7 ft per day, and its tracks can be removed to facilitate later reclaiming with shovels.

From the stockpiling standpoint, the port facility on Lake Superior is equally interesting. It provides the surge between rail transportation from plant and vessels serving lower lakes steel plants. This is a 1200-ft dock with a railroad trestle and about 100,000-gross-ton dock storage bins, together with 25 pushbutton-operated shuttle belt conveyors, which can load two ore boats simultaneously. Taconite pellets flow from railroad cars into the storage bins and then to reciprocating feeders and shuttle belt conveyors which are positioned over alternate hatches of the ore vessel. Each shuttle belt can load and trim either 750 or 1500 tph. to lake vessels.

The pellets are stored in bulkhead type surge bins. Four 96-car trains move to the harbor daily. They run over a trestle above the storage bins, and the pellets are dumped from special dropbottom cars without uncoupling.

The method of loading boats and the arrangement of the loading system at the dock are quite simple, yet the magnitude of the operation created unusual problems of control and communication.

Functions of feeding, conveying, advancing, retreating, and weighing are controlled separately for each conveyor from one of two control towers on the dock. Construction and location afford the operator an unrestricted view of the loading operations but he is also equipped with measuring gages for control.

Controls for a bank of 12 conveyors are grouped in one operating tower, those for the remaining 13 in the other. This provides for one bank of conveyors for each vessel, making it possible for one operator to load and trim up to 13 alternate hatches at one time.

One of the most complex bulk storage facilities has recently been put in operation on the lower Mississippi river. This is a public marine terminal designed to receive bulk materials from ocean vessels or barges and to ship out to similar carriers.

The dock has a rated annual capacity of 4 million tons and facilities for handling numerous types of bulk materials, including bauxite, caustic soda, alumina, phosphate, coal, iron ore, manganese ore, and chrome ore. Bauxite is delivered to a 500-ton surge bin, then to a crusher building. The dried bauxite is stored under cover (see low building at far right) and is subsequently reclaimed to an alumina plant (center background). The alumina is conveyed to boat-loading facilities by the gallery, shown at upper left in the photo. The cross conveyor in the center of the picture has a tripper for stockpiling bulk materials suitable for storage in the open area beneath the conveyor.

Stockpiling in some form is required in almost every industry extracting and processing bulk materials. Problems result from infinite combinations of basic design and operational factors. Selection of methods and tools for stockpiling should be based on experience sufficiently broad to anticipate the effects of these combined factors. Often, successful solutions in one industry may, with appropriate modification, be applied to another industry. Best results are obtained by close cooperation between engineering and operating departments of both user and manufacturer of stockpiling equipment.

SELF-FLUXING SINTER

by THOMAS E. BAN, CHARLES D. THOMPSON, and CHARLES A. CZAKO

Continuous sintering—a metallurgical process for more than 50 years—has broadened from its origin in nonferrous metallurgy to present-day applications in ferrous, chemical, and nonmetallic fields.

During the past year, self-fluxing sinter production has been a subject of active interest to iron metallurgists in North America. Accomplishments however, have come predominantly from Europe and proper interpretation of these reports requires an understanding of European raw materials and European economics. The technology, of course, can be applied universally.

Calcination of 100-pct charges of limestone, and formation of cement clinker has had practical and commercial applications by the Dwight-Lloyd sintering process.[1,2,3] Portland cement clinker containing less than 1 pct free lime has been made at the Dwight-Lloyd Research Laboratories, and this has been made from raw material composed of 80 pct limestone and 20 pct shale. Sinter bed temperatures in these cases are invariably in excess of 2600°F. In comparison, self-fluxing sinters of iron ore are generally formed at temperatures several hundred degrees lower than cement clinker and the ore mix has only a fifth the quantity of limestone.

Continuous sintering of iron ore by the Dwight-Lloyd process can be reviewed by referring to the Fig. 1 diagram. This shows the hourly flowsheet as a material balance at the Dwight-Lloyd Research Laboratories and the data represent averages of several repetitious pilot-plant campaigns. A methodical error always existed in seeking 100-pct recovery in the materials balance, and this error is expressed as a tolerance of the returns cycle. The fact that this value is only 0.25 pct gives an indication of the precision exercised in acquiring the data.

The materials balance diagram illustrates several features of good sinter practice. These are related to sintering a nodular-textured burden and the use of a hearth layer. The air-borne solids amounted to less than 0.2 pct of the sinter and only 2.7 tons of draft were used per ton of sinter at a vacuum of less than 20 in. water gage. Unit sinter capacity acquired from this ore (-⅜ in. Lake Superior fines) amounted to 3.67 net tpd per sq ft. For comparison, a similar materials balance diagram in Fig. 1A shows the sintering characteristics of an iron ore that responds less favorably. Air-borne solids in this case amounted to more than 1 pct of the sinter, 5.8 tons of draft were required per ton of sinter, and a unit sinter capacity of only 1.29 net tpd per sq ft was acquired. These marked differences were attributed to the characteristics of the raw materials.

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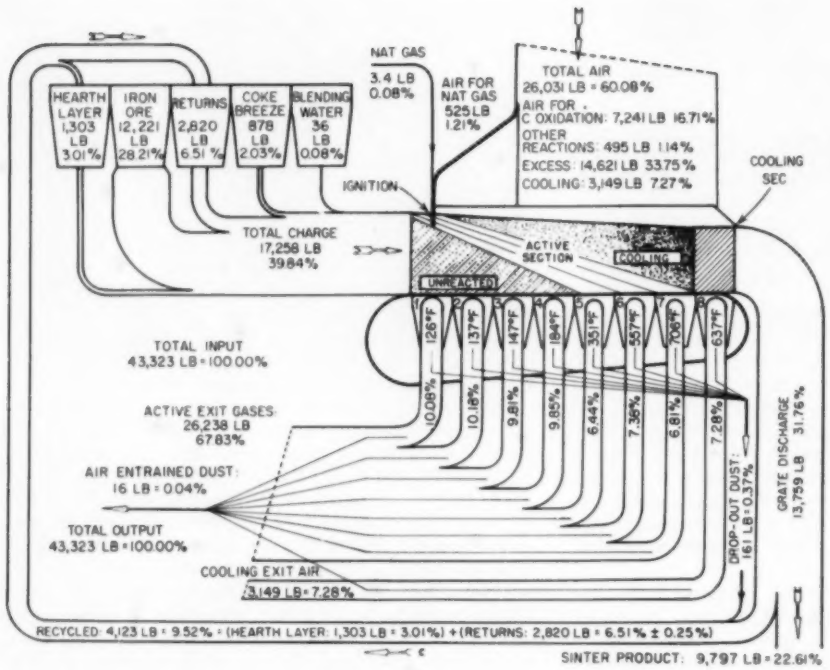
Many previous investigators have reported their versions of the mechanics of sintering.[4-9] Generally there has been agreement concerning all principal characteristics. The continuous process is maintained by subjecting a bed of fine, moistened materials to heat developed by combustion of fuel within a moving bed while the individual particles are maintained in the quiescent state. This is conducted in the downdraft process, illustrated in the diagram, by charging a blend comprised of ore, returns, coke breeze, and water on top of hearth layer which is applied directly on the pallets. As the charge emerges under the ignition burner, a continuous downdraft promotes combustion and heat transfer. This gives rise to the five prominent zones of sintering, i. e., cooling, firing, calcining, drying, and unreacting. The firing or combustion zone terminates near the discharge end, and here peak exhaust temperature naturally occurs.

The sectional views in Fig. 2 show the heat zone patterns from sections throughout the bed. Data for these temperature curves were derived from batch tests and are illustrated as typical for the zones described previously. The peak bed temperatures for proper sintering are governed by the eutectic point for the *semi-fused* mass, provided sufficient intensity of combustion is maintained by fuel and draft. The eutectic point is altered by varying the composition of the charge. This is an important consideration in forming self-fluxing sinter. These curves also illustrate the rather rapid air quenching during sintering. In cases of forming self-fluxing sinter, where about half the volume of sinter is composed of a friable glassy slag, a rapid air quench can produce a friable sinter by thermal stresses.

Classifications of self-fluxing sinter have unfortunately ranged from sinter that contained a part of its own fluxing needs to sinter that contained fluxing requirements for an entire smelter charge including the ingredients of the sinter, ash of the reductant, and the extraneous ore charge. To qualify the various ranges of self-fluxing sinter, an attempt will be made here to define the basicity of the sinter as a

weight ratio $\left(\frac{CaO + MgO}{SiO_2}\right)$.

Non-Ferrous Applications: Self-fluxing sinter applications originated in the nonferrous metallurgical field. Probably the initial approach was made in 1896 when Huntington added lime to his pot charge to "enhance the oxidation of the lead sulfide."[9] Though actually the addition was a charge diluent, subsequent investigators added gypsum, limestone and sand.[10] It was natural that the diluent used ultimately for efficient blast furnace smelting would be the flux of self-fluxing sinter. More than 20 years ago the reports led to text book information that the regular lead blast furnace which smelted 100 tpd of charge



Dwight-Lloyd Sintering Process

Fig. 1—Materials balance flowsheet for iron ore A.

could smelt 250 tpd from a 100-pct sinter charge and improve to 600 tpd by using 100 pct self-fluxing sinter.[10,11] These self-fluxing sinter applications, in the modern nonferrous smelter, have led to the use of a bedding system for layering limerock, siderite, and other diluents with the ore as presinter treatment.[12] An interesting process of making self-fluxing lead sinter at the Boliden smelter *sandwiches* the flux on pellets of raw constituents prior to sintering.[13] This is in conjunction with electrothemal smelting of rich lead charges. Flux is used at the Josephtown smelter to strengthen zinc sinter for smelting in vertical shaft-type electrothermic furnaces. Sand is added to provide 8 to 9 pct SiO_2 in the sinter product—this imparting necessary hardness and structure.

Lime Additive for Improving Sintering Characteristics: Silica is the predominant gangue of iron ores. Ores similar in grade to Lake Superior iron ores generally have a $\frac{Ca+MgO}{SiO_2}$ ratio of less than 0.1. For this reason, research on effects of additives on iron ore agglomerates has centered on use of basic or neutral additions. Slags, calcium oxide, and magnesium oxide have been extensively tested. The quantities have been intentionally limited to additions of a few percent of additive rather than attempts to approach self-fluxing consistency of agglomerates.

Strength of sinter and of indurated iron ore agglomerates is attributed to bonds of a ceramic nature and to the phenomenon known as grain growth. These attributes have been widely discussed by many authors.[14-19]

Identification of the bond sources have been conducted by petrographic microscope, powder X-ray diffraction, and micro-radiography methods. Bonds of a ceramic or slag nature are important with regard to self-fluxing sinter. The general contributants to all bonds on the acid side are SiO_2 and Fe_2O_3, whereas those on the basic side are CaO, MgO, and FeO. Naturally, slags within sinter composed of these chemicals contain a wide range of crystals and solid solutions. Prominent crystals within sinter bonds have been: belite ($2CaO \cdot SiO_2$), wollastonite ($CaO \cdot SiO_2$), fayalite ($2FeO \cdot SiO_2$), and mono-calcium ferrite ($CaO \cdot Fe_2O_3$).

The low melting points of some of these compounds and their eutectics of solution have led to considering them as fluxes for sintering. Khokhlov illustrated the rates of formation of some of these compounds in the solid state and showed monocalcium ferrite formation to be 60 pct complete at about 1500°F, whereas di-calcium silicate required a temperature of about 2000°F.[19] He also showed a eutectic point to exist at 2183°F between monocalcium and hemi-calcium ferrite. These low-temperature fluxing effects of CaO caused investigators to consider lime additions in sinter. Fluxing inhibits the formation of magnetite and fayalite.

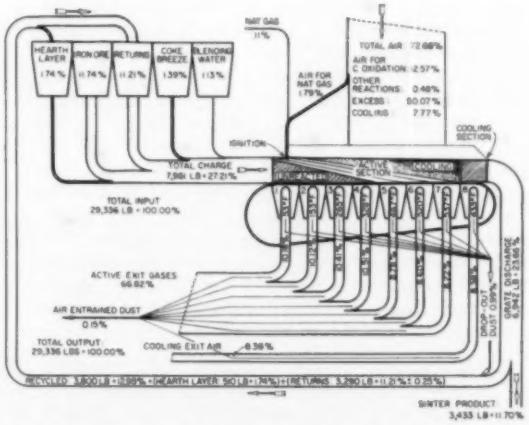


Fig. 1A—Materials balance flowsheet for iron ore B.

Results of several investigators, who studied lime addition to iron ore agglomerates, are presented in Table I. The Jernkontoret and Cleveland-Cliffs results show strength improvements from lime additions to iron ore pellets with a wide range of basicity.[21, 23] Slight additions of lime to sinter mixes at low basicities seemed to improve strength. The IRSID and Urals Institute reports, however, showed the strength (depicted as mean degraded size) to decrease at higher basicity.[19, 21] It is quite possible that an optimum slag quantity within agglomerates exists for specific raw materials as suggested by Cooke and Ban.[24]

A survey of the literature has shown investigators reporting that FeO content of sinter decreases with lime additions. This was generally accompanied by an increase of reducibility as explained by the diffusion-controlled phenomena.[15, 19, 26, 30, 37, 38]

Tigerschiold and Edstown have both illustrated how fluxed agglomerates possess higher strength than normal agglomerates at elevated temperatures and under reducing conditions.[23, 25] This factor, though not thoroughly evaluated for iron ore sinter, may show that self-fluxing sinter charges have greater blast furnace *strength*. Apparatus and techniques described by Linder showed how laboratory work can be used for this type of evaluation.[14] Linder compared sinter under conditions that simulated blast furnace thermal and chemical changes and, though the sinters were from different sources, a self-fluxing variety was slightly stronger than the normal variety.

Additions of pure MgO have caused reductions in strength of iron ore agglomerates,[20, 24] but limestone containing up to 25 pct magnesia has shown improvement in sinter quality.

As illustrated in Table II, lime and limestone have improved the sintering process, the improvements generally related to increased permeability and sinter rate. Usually the lower fusion bed temperature allows a more rapid flame front which in turn prevents moisture condensation. An interesting heat balance around a self-fluxing sinter system showed less heat was needed for sintering than in normal sinter practice, despite the necessity of calcining about 20 pct limestone.[19] These calculations showed that the lower bed heat capacity at fusion point, the lower iron oxide reduction, and the exothermic heat of slag formations realize a greater heat value than the endothermic reaction of calcining limestone.

Research on Self-Fluxing Sinter: A series of batch sinter tests was conducted at the Dwight-Lloyd Re-

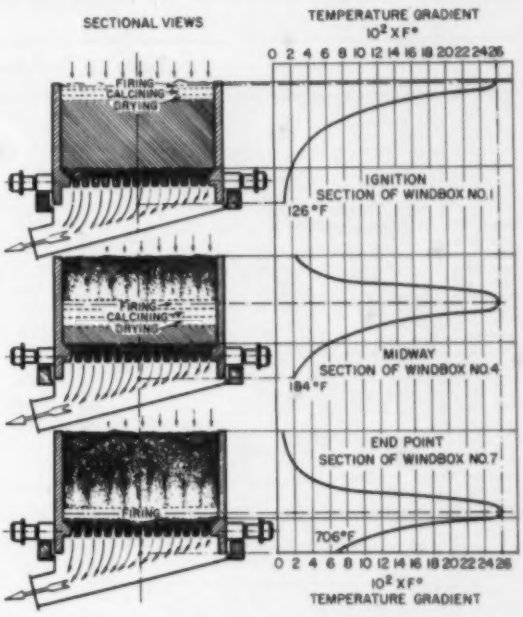


Fig. 2–Typical heat zone patterns through Dwight-Lloyd iron ore sinter bed.

Table I. Effect of Additives on Strength of Agglomerate

Institution	Name of Ore	Type (Mesh-Mineral)	SiO_2, Pct	Agglomerate	Additive, Pct	Basicity	Strength Improvement Attributed to Additive (Multiple of Original Strength)
University of Minnesota[20]	Gogebic	−14-mesh hematite	10.9	Sinter	4 CaO	.37	6.20 mean degraded size
Urals Institute[19]	Krivoi Rog	−½ in. hematite	17.8	Sinter	14 $CaCO_3$	.44	1.45 mean degraded size
IRSID[21]	Acerias Paz del Rio	−½ in. hematite	9.5	Sinter	10.7 $CaCO_3$	.68	0.85 mean degraded size
U.S. Steel, South Works[18]	Flue dust-ore fines	−½ in. hematite −20-mesh flue dust	9.4	Sinter	2.4 CaO	.47	1.10 mean degraded size
Jernkontoret[22]	Malmberget concentrates	−150-mesh magnetite	0.16	Pellets	3 CaO	18.70	1.70 crushing strength
Cleveland-Cliffs[23]	Humboldt concentrates	−65-mesh hematite	7.3	Pellets	2.5 $CaCO_3$	.30	3.00 crushing strength

Table II. Effect of Additives on Sintering Characteristics

Institution	Name of Ore	Type	SiO_2, Pct	Additive	Basicity	Improvements: Capacity	Improvements: Air Flow
BISRA[30]	Sierra Leone concentrates	Hematite concentrates	4.2	4-pct limestone	0.525	Sinter rate increased 55 pct	Air requirement diminished 43 pct
Oliver Mining Co.[31]	Taconite concentrates	Magnetite concentrates	8.12	5-pct limestone	0.442	*	Sinter vacuum diminished 27 pct
Inland Steel Co.[32]	Ore screenings, flue dust, scale	Mixture	*	5 to 7-pct lime hydrate	*	Sinter rate increased 60 to 65 pct	Permeability increased 200 pct
Steel Co. of Canada Ltd. (Stelco)[33]	Ore screenings, flue dust, scale	Mixture	13.4	20-pct dolomite	1.050	Sinter rate increased 22 pct	*
USSR Plant B[34]	*	*	11.7	10-pct limestone	0.600	Sinter rate increased 15 pct	*
Urals Institute[19]	Krivoi Rog	Hematite	17.8	14-pct limestone	0.440	Sinter rate increased 50 pct	*

* Not designated.

search Laboratories to investigate self-fluxing sintering characteristics of a normal Lake Superior iron ore. The tests were designed to determine the effect of sintering a $-\frac{3}{8}$-in. iron ore fluxed to a $\frac{CaO + MgO}{SiO_2}$ ratio of 1.4 with: 1) $-\frac{1}{8}$-in. high-magnesia limestone, $\frac{CaO}{MgO}$ ratio of 6, 2) −100-mesh high-magnesia limestone, 3) −100 mesh limestone, and 4) −100 mesh hydrated lime. Four repetitious tests were conducted with each burden and the results are expressed in Table III as a mean value, with its probable deviation. A nodular charged burden was used in each case and the following conditions of operation were closely controlled: 1) percentage of returns and coke, 2) blending retention time, 3) bed charge depth and hearth layer depth, 4) ignition intensity, and 5) exhaust draft flow rate.

The sinter test results are expressed in terms of draft vacuums, unit capacities, and size analyses before and after tumble testing. It was apparent that differences in sintering characteristics of all the self-fluxing burdens were minor. Significant

Table III. Self-Fluxing Sinter Test Results

		Self-Fluxing Sinter			
	Normal Sinter No Additive	−¼ In. High-MgO Limestone Additive	−100 Mesh High-MgO Limestone Additive	−100 Mesh Pure Limestone Additive	−100 Mesh Hydrated Lime Additive
Sinter Charge Composition (as received)					
Ore, pct	71.00	56.00	56.49	57.60	60.30
Flux, pct	—	15.00	14.51	13.40	10.70
Returns, pct	25.00	25.00	25.00	25.00	25.00
Coke, pct	4.00	4.00	4.00	4.00	4.00
Sintering Conditions					
Burden moisture, pct	10.5±0.1	10.5±0.5	10.7±0.3	10.2±0.1	11.9±0.5
Retention blend, sec	60	60	60	60	60
Ignition period, sec	45	45	45	45	45
Flowrate, cfm per sq ft (NTP)	206±2	208±2	210±1	214±7	206±6
Vacuum, in. H_2O	12.1±0.7	9.0±0.1	11.7±0.3	9.2±0.9	8.9±0.2
Sinter Production					
−⅜-in. generated, pct	37±1	40±1	46±1	39±2	41±1
Net tons per sq ft per day of −4 in. +0 in.	3.4±0.2	3.6±0.1	3.1±0.2	3.3±0.1	3.5±0.1
Net tons per sq ft per day of −4 in. +⅜ in.	2.8±0.1	2.8±0.2	2.1±0.2	2.6±0.1	2.7±0.1
Median size of +⅜ in., in.	1.1±0.10	0.63±0.01	0.60±0.01	0.66±0.03	0.67±0.06
Tumble-Tested Product					
Percent −28 mesh	8.4±0.9	6.0±0.3	6.2±0.8	3.3±0.5	5.7±0.8
Median size, in.	0.320±0.006	0.25+.000	0.230±0.006	0.250±0.010	0.24+.000
Percent −28 mesh of weathered product	4.5	6.8	5.4	5.8	4.9
Median size of weathered product, in.	0.35	0.25	0.25	0.26	0.27
Sinter Grade					
Percent of Fe total	6.70	53.12	52.68	54.37	53.35
Percent of FeO	20.75	9.87	9.13	11.32	9.29
$\frac{CaO + MgO}{SiO_2}$ (calculated)	0.029	1.40	1.40	1.46	1.42
$\frac{CaO + MgO}{SiO_2}$ (analyzed)	0.044	1.42	1.31	1.50	1.69

Table IIIA. Self-Fluxing Sinter Test Results

	Normal Sinter No Heat Treatment	Self-Fluxing Sinter			
		No Heat Treatment	Annealed	Annealed	Annealed
Sinter Charge Composition (as received)					
Ore, pct	71.00	56.00	56.88	56.88	56.88
Flux, Pct	—	15.00	15.24	15.24	15.24
Returns, pct	25.00	25.00	25.38	25.38	25.38
Coke, pct	4.00	4.00	2.50	2.50	2.50
Sintering Conditions					
Burden moisture, pct	10.5±0.1	10.5±0.5	10.7±0.3	9.8±0.2	10.2±0.2
Retention blend, sec	60	60	60	60	60
Ignition period, sec	45	45	45	45	45
Annealing period I					
Time, min	—	—	5	5	24
Air temp, °F	—	—	1820±11	1933±23	1900
Annealing period II					
Time, min	—	—	6.5±0.8	6.5±0.4	—
Air temp, °F	—	—	Ambient	608±54	—
Flowrate, cfm per sq ft (NTP)	206±2	208±2	178±2	154±5	168±4
Vacuum, in. H_2O	12.1±0.7	9.9±0.1	36	36	36
Sinter Production					
−⅜-in. generated, pct	37±1	40±1	53±1	50±5	40±3
Net tons per sq ft per day of −4 in. +0 in.	3.4±0.2	3.6±0.1	2.7±0.3	2.8±0.1	1.4±0.1
Net tons per sq ft per day of −4 in. +⅜ in.	2.8±0.1	2.8±0.2	1.6±0.2	1.8±0.3	1.1±0.1
Median size of +⅜ in., in.	1.1±0.10	0.63±0.01	0.77±0.02	0.78±0.03	2.44±0.60
Tumble-Tested Product					
Percent −28 mesh	8.4±0.9	6.0±0.3	6.3±0.4	6.6±0.8	7.5±0.9
Median size, in.	0.320±0.006	0.250+0.000	0.290±0.005	0.280±0.010	0.290±0.020
Sinter Grade					
Percent of Fe, total	61.70	53.12	51.35	50.70	51.53
Percent of FeO	20.75	9.87	8.16	6.17	5.35
$\frac{CaO + MgO}{SiO_2}$ (calculated)	0.029	1.40	1.45	1.45	1.45
$\frac{CaO + MgO}{SiO_2}$ (analyzed)	0.044	1.42	1.50	1.60	1.55

differences were observed, however, between normal burdens and self-fluxing burdens. Generally in cases of self-fluxing sinter the percent of generated returns were higher and median sizes were lower. Very slight differences existed between vacuum conditions and unit capacities. These were attributed to the fact that nodular burdens with inherent high unit capacities were obtained for both kinds of sinter making.

In order to acquire a true size analysis of the product, special care was used to crush and screen the grate discharge. Results of the method of analysis were surprisingly consistent as was evidenced by the probable deviation of the median sizes and percent generation of returns. These are indicated in Table III.

Tumble tests were conducted on a 20-lb representative portion of the +⅜-in. sinter from each test. This was conducted with an ASTM coke-tumbling drum operating at 24 rpm for 200 revolutions. Size analyses of the degraded sinter were determined in a manner similar to that used for the grate discharge. Tumble tests were also conducted on a sample of each series of sinter subjected to a simulated weathering test. The *weathering* was accomplished by a 10-day cycle of repeated wetting and drying of sinter product. Samples representative of each of the four series were submerged in water for 24 hr and then drained and air-dried for 24 hr. Results of the tumble-tested weathered specimens are given in Table III.

The families of size analyses curves in Fig. 3 illustrate the results obtained from all the tests. The broad-banded area of the curves contains the test results, including the size analyses of the raw materials, the sized sinter (normal and self-fluxing), and the tumbled sinter (normal and self-fluxing). The self-fluxing sinters illustrated in their respective bands contain all of the results of the coarse and fine magnesia limestone tests, the fine limestone tests and the lime hydrate test, and each of their respective weathering tests.

Interpretation of these curves leads to some interesting observations. The raw materials and the sized sinter curves resemble a hyperbola about the diagonal, and the reversion of the sinter structure to the structure of raw materials is illustrated by the structure of the degraded sinter. In other words, the more closely the degraded sinter curve approaches the raw materials curve, the greater the degradation. Inflection of the top portion of the sized sinter curves indicates degradation of coarse sized material and inflection of the lower portion indicates creation of fines. These clearly illustrate that the self-fluxing sinter possessed a smaller median size and degraded to a smaller median size.

In all cases the degradation tests showed that self-fluxing sinter had a greater tendency to revert to a structure of hearth layer (*popcorn*) without creation of more dust. Naturally, the sinter possessed less lump material.

There were no obvious differences in strength of the various grades of self-fluxing sinter formed from the various types of additives, and there was no extreme weakening caused by the weathering tests.

If the small median size of self-fluxing sinter is objectionable from a quality standpoint, it can be improved by annealing the sinter. This is accomplished by using a preheated draft for combustion or an extended ignition in place of solid carbon

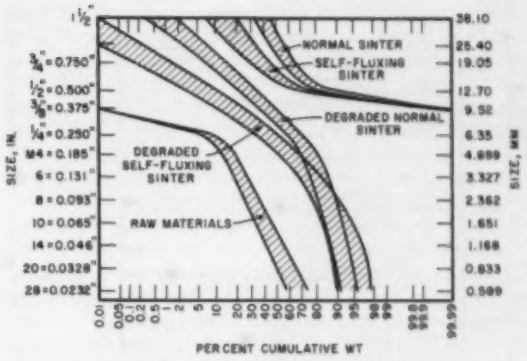


Fig. 3—Size analyses family of curves.

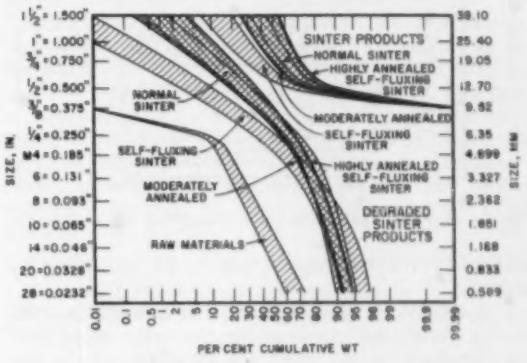


Fig. 4—Size analyses family of curves showing effect of annealing self-fluxing sinter.

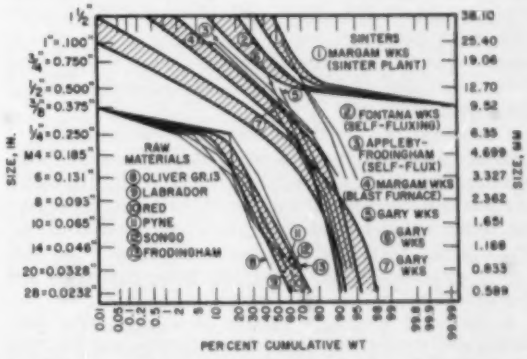


Fig. 5—Size analyses family of curves showing commercial raw materials and sinter structures.

fuel. A series of sintering tests with varying intensities of annealing were conducted in this manner and the results are shown in Table IIIA. For purposes of comparison this table includes both results for normal sinter and for −⅛-in. high-MgO limestone self-fluxing sinter formed by standard techniques as they were shown in Table III. The annealed-sinter tests were conducted by using 2.5-pct coke instead of 4 pct, and by using preheated draft for various periods of time. In the first case, a draft of 1820°F was maintained for 5 min immediately after ignition and was followed by an ambient temperature draft until the termination of the run. In the second case a draft of 1933°F was maintained for 5 min after ignition and was immediately followed by a draft of 608°F for 6.5 min. In the third case a

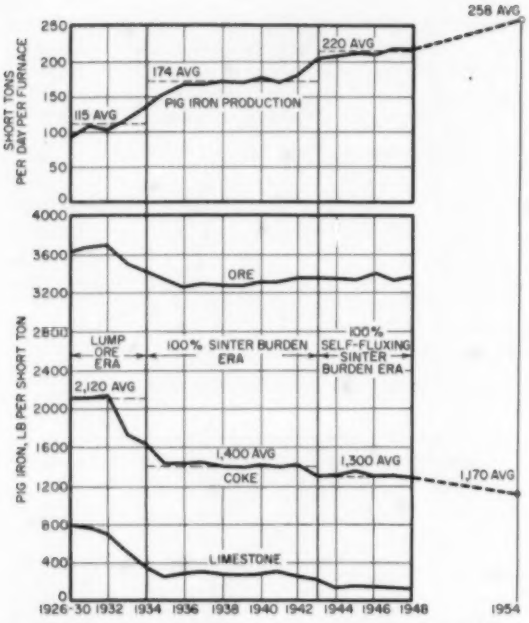


Fig. 6—Tigerschiold's data on Domnarfvet blast furnace.

draft of 1900°F was maintained for 24 min following ignition.

The results showed that median size of the self-fluxing sinter increased as the intensity of annealing increased. In all cases the structure of the annealed self-fluxing sinter was an improvement over the usual self-fluxing sinter structure, and the highly annealed self-fluxing sinter was coarser than the normal sinter. In comparing the annealed sinter tests with the standard sintering tests, it was apparent that the vacuum conditions were higher and unit capacities and FeO analyses were lower for the annealed sinter.

Fig. 4 shows how the structure of annealed self-fluxing sinter compares with normal sinter and self-fluxing sinter made by standard sintering techniques. The curves of the annealed self-fluxing sinter are represented by the cross-hatched banded areas. The coarser extremes are characteristic of the most highly annealed state, while the finer extremes are characteristic of the moderately annealed state.

A series of structure curves of various raw materials and production sinter are superimposed on the standard self-fluxing sinter curve study in Fig 5. These show relationships between sized sinter and degraded sinter with size analyses of materials used and formed in production sinter plants.

Benefits of Smelting Self-Fluxing Sinter: Several qualitative factors suggest self-fluxing sinter would be a more satisfactory blast furnace feed than normal sinter. These are as follows:

1) The normal limestone charge would be thoroughly dried and calcined.

2) Flux constituents with a sinter furnace charge would be intimately blended and vitrified (preslagged).

3) The sinter would contain less FeO and have higher reducibility.

4) Normal CO_2 from calcination of limestone is not present, so there is no interference with indirect reduction and solution loss is minimized.

5) The blast furnace can revert to its primary duty of reducing iron ore.

Regardless of these postulates, operators using high quantities of self-fluxing sinter have shown coke rates diminish and blast furnace productivities increase.[35, 39-50] These are generally substantiated by a decrease of $CO:CO_2$ ratios in top gas and by smoother furnace operations.[35, 40, 37] Tigerschiold showed CO_2 in top gases to increase from 9 to 13 pct by use of sinter instead of lump ore and from 13 to 15 pct by use of self-fluxing sinter instead of normal sinter, despite the lack of CO_2 from stone calcination within the furnace.[40] This indicates less solution loss or more indirect reduction or both.

Table IV is arranged to illustrate benefits gained by various operators who used self-fluxing sinter burdens instead of normal burdens. The results are extracted from their reports and an attempt has been made to use values of their data that illustrated comparable percentages of normal and self-fluxing sinter burdens. Production data on higher self-fluxing sinter burdens than those given in Table IV were available, for instance, at ISCOR and Stelco, but data on comparable normal sinter burdens were not available. The results of Domnarfvet experiences are notable for their improvement and represent the longest period of survey (more than 10 years duration for each type of sinter). Some of the other data were of limited duration but apparently sufficient, as shown by the confidence of the organization in publishing the results. Naturally, other factors than the use of self-fluxing sinter influenced the improvement of blast furnace performances. These factors cannot be isolated here and the benefits of furnace performances are attributed mainly to the use of self-fluxing sinter.

Table IV. Comparison of Normal and Fluxed Sinter Burdens on Blast Furnace Performance

Plant	Blast Furnace Capacity, Tpd	Grade of Fluxed Sinter, Pct	Sinter in Burdens, Pct		Sinter Basicity, No.		Improvement Through Use of Fluxed Sinter	
			Normal	Fluxed	Normal	Fluxed	Production Increase, Pct	Coke Rate Decrease, Pct
Domnarfvet[35, 40]	530	53	100.0	100.0	0.71	1.65	17.0	11.0
Magnitogorsk combine[34, 38]	*	55	64.5	86.4	0.30	1.26	11.1	12.2
USSR plant B*[34]	*	57	75.7	64.4	0.12	0.60	6.0	5.3
Kaiser[45]	1300	*	58.0	50.0	*	*	8.0	4.0
Makeevka[37]	900	50	50.0	50.0	*	*	10.5	4.0
German foundry*[33]	400	42	45.0	50.0	*	0.88	10.0	15.0
ISCOR[39]	650	58	40.5	37.9	0.02	0.70	11.0	2.0
Stelco[38]	858	54	40.0	38.0	0.16	0.80	1.8	2.7

* Not designated.

Apparently, a more marked improvement is realized by using self-fluxing sinter in a smothered-arc electric furnace for pig iron. Both Collin and Kalling report that approximately 15 to 20 pct of the electrical energy is conserved through the use of self-fluxing sinter and this generally contributes 15 to 20 pct to the increase in furnace capacity.[41, 42] Thermochemistry would show a CaO flux charge to conserve 5 to 10 pct of the energy that would be consumed in a $CaCo_3$ flux charge. The additional improvement is attributed to solution loss and efficiency of furnace operations.

Perhaps Tigerschiold's record of the Domnarfvet blast furnace history best illustrates the benefits of using self-fluxing sinter.[43] The graph in Fig. 6 shows the furnace production and burden charges for the Domnarfvet furnaces from 1926 to 1948. Prior to 1934, lump ore was used as the furnace charge; from 1934 to 1943 the charge was comprised of normal sinter; and from 1943 to 1948 self-fluxing sinter was used. These dates, extended to the 1954 records, are presented as Domnarfvet improvements in Table IV and Fig. 6.[38] Progressively, through evolution of practice since 1926, the coke rate decreased more than 40 pct, while the furnace productivity more than doubled.

The magnificent accomplishments of Domnarfvet in acquiring a coke rate of 1170 lb per ton of metal with a capacity of 3.2 tpd per sq ft of furnace hearth area are benefits evolving from 32 years of work.

Summary and Conclusions: Though self-fluxing sinter applications originated with nonferrous metallurgy in the U.S., extensive practices in ferrous metallurgy have been applied in Europe. A considerable amount of research work involved additions of small percentages of lime to iron ore agglomerates, with attendant benefits to sinter capacity and sinter strength. Large additions of limestone, approaching self-fluxing consistency, cause a weakening of the top or lump structures of sinter. This does not lower the sinter resistance to dust formation, however, and the weakening can be inhibited to a considerable extent by using a preheated draft for sinter making.

Users of self-fluxing sinter in blast furnaces and submerged-arc electric furnaces have reported an increase in furnace capacities and a decrease in thermal rates. There are many technical explanations for these improvements.

Iron blast furnace burdens of 100 pct self-fluxing sinter have been used for a number of years at Appleby-Frodingham in England, at Domnarfvet in Sweden, and at the Magnitogorsk combine in the Soviet Union. It is apparently economical practice at these plants. Discretion should be used, however, in translating this practice without meticulous evaluation. The relatively high cost of European metallurgical coke is a compelling factor for consideration of highly beneficiated burdens, and rather unique raw materials have also influenced the application.

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THE SHEAR STRENGTH OF ROCKS

A discussion of a third factor in the theoretical aspects of rock failure, with the view that shear strength is the missing link in drilling and blasting research.

by RUDOLPH G. WUERKER

With stepped-up work in rock mechanics, more and more data on strength and elastic properties of rocks has become available. Results of measurements of tensile strength, in addition to determinations of compressive strength, allow us to determine, even if only in an approximate way, the third property influencing failure of a brittle material: shear strength.

It is fairly generally agreed upon in rock mechanics, in drilling and blasting research, that Mohr's theory provides an acceptable method for explaining the failure of a brittle material. Mohr states that a material may fail either 1) through plastic slip when shearing stress Y in the planes of slips has reached a limiting value (which in general depends on the normal stress, X, acting normal to the surface), or 2) when the largest normal tensile stress has reached a limiting value. The mode of failure depends upon which of the two stresses is the smaller.

Everyone who has run compression tests has observed these fracture phenomena. Weak rocks merely crumble, with hardly any wedge-type fragments noticeable. Medium-strong and strong rocks may show either of the following: 1) They split at first in wedges, indicative of shear failure, or 2) upon further loading they split by tension into pieces separated by longitudinal tension cracks. This sequence may be reversed, or the two modes of failure can take place simultaneously, depending on particular details of the tests. As will be shown below, Mohr's theory can be used to explain this ambiguous behavior of brittle materials.

Another pertinent observation from confined tests is that rocks, ores, coal, etc., which are brittle when tested as small specimens and unconfined, can be brought into the plastic state under sufficient constraint. Nadai[24] points out that "it is more correct to speak, not of brittle or ductile materials, but rather of the brittle or plastic state of these materials." The mineral engineer in his daily work may encounter either state.

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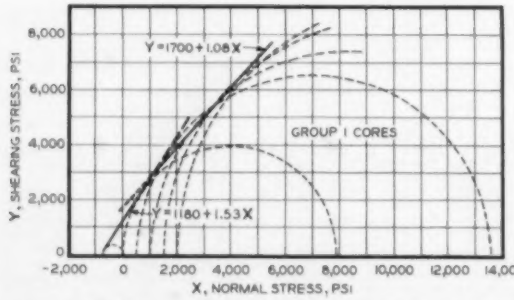


Fig. 1—Mohr's envelope of subgraywacke, P-5620-A (After U. S. Bureau of Reclamation Concrete Laboratory Report C-746, fig. 5.)

DETERMINING SHEAR STRENGTH

Shear strength of rocks can best be determined by triaxial compression tests. A complete description of the procedure of measurements and method of evaluation is given in publications by the U. S. Bureau of Reclamation[1, 5, 9] and by other investigators.[5, 8, 22, 28] Included are numerous results of tests of rocks that particularly interest the mineral engineer. Many are presented in graphical form using the method established by Mohr.

Mohr's envelope, sometimes referred to as Mohr's rupture line, defines the limiting state of stress possible before failure. Referring to Fig. 1, fracture will occur when the combination and magnitudes of the *stresses* are such that the semi-circle touches the rupture line. Two methods of interpretation are customary: 1) curvi-linear relationship, and 2) straight line fit. Presentation of results of triaxial testing as a curve is more accurate and will have to be used in higher ranges of confining stress.

For rough approximations and in all cases where tests under confining pressure cannot be made, use of tensile and compressive strength data suggest themselves. A straight line tangent is drawn from the tension circle to the compression circle. The U.S. Bureau of Reclamation has presented the data[9] of

such a comparative test. The rock under investigation was a coarse grained subgraywacke, P-5620A (see Fig. 1). The shearing stress relationships were based on: 1) triaxial compressive strength (expressed as straight line: $Y = 1700 + 1.08\ X$); 2) unconfined compressive and tensile strength ($Y = 1180 + 1.53\ X$). In general terms, and assuming Mohr's envelope to be linear, the equation of Mohr's envelope is $Y = C + tan\ \phi\ X$ where Y is the shearing strength and X is the normal stress at failure. The intercept of the envelope with the Y axis is C, which is the shear strength at zero normal stress, the quantity which is the object of this discussion. It is sometimes referred to as unit cohesive strength. The slope of Mohr's envelope, $tan\ \phi$, is sometimes called the coefficient of internal friction.

The disagreement between the two expressions for the envelope of the subgraywacke pictured in Fig. 1 can be explained by the fact that linear equations were assumed in both cases, whereas the true relation is a curvi-linear one. The true value probably lies between the value obtained from confined tests and that obtained from unconfined tensile and compressive strengths. It lies as a rule on the high side of the values arrived at in this investigation; the straight line approximation is always on the safe side, as it is the smaller value. Also the validity of the straight line will have to be established from case to case. Beyond this point, results of tri-axial testing will have to be presented as a curve.

In many cases, the judicious use of schematic Mohr's envelopes allows extrapolations that can be used to predict conditions in the confined state. Referring again to Fig. 1 the value $X = 2000$ psi may be chosen for this check. A confining stress of 2000 psi is roughly equivalent to a depth of 2000 ft, which is greater than the depth of most U. S. mining operations. Graphed values from the actual test and from the approximation compare as follows:

	Triaxial Tests	Straight Line Approximations
Shear strength at 0 confining stress	1180 psi	1700 psi
Shear strength at 2000 psi confining stress	3800 psi	4300 psi

The difference in the results obtained by the two methods is reasonable in the range from 0 to 2000 psi confining pressure.

While use of this timesaving procedure must recognize its limitations and caution must be used when determining properties of a specific rock, it is of great help when discussing the behavior of rocks, or other brittle material. Fig. 2A shows a schematic Mohr's envelope of a ductile material such as mild steel which can be visualized as having equal compressive and tensile strength at the proportionality limit. Fig. 2B shows the schematic envelope of a material such as rock, cement, brass, cast-iron and cast steel, with unequal compressive and tensile stress at failure. Fig. 2C is a special case—a material having no tensile strength, e.g. soil.

Evaluation of Tests of Rocks: In Fig. 3, schematic but representative Mohr's envelopes of two rocks and one concrete sample are pictured. All drawn to the same scale, they show how the slope of the envelope and the intercept with the shear axis of various materials can change. The rock depicted in Fig. 3A is a jaspilite from the Soudan mine, in Minnesota (USBM Ref. no. 8.4). In Table I, it is the

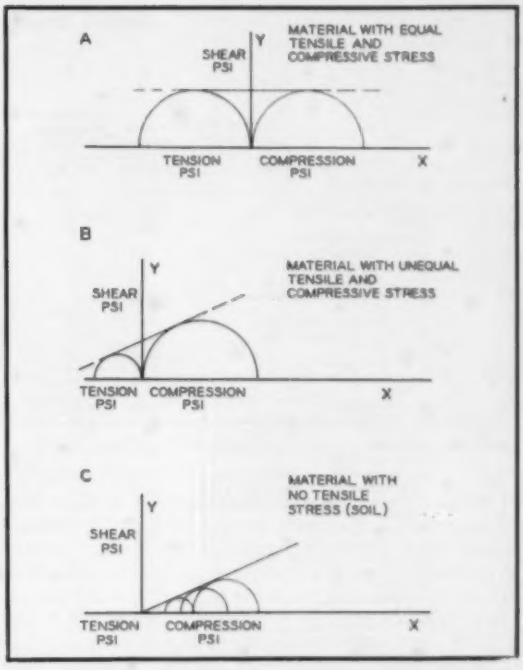
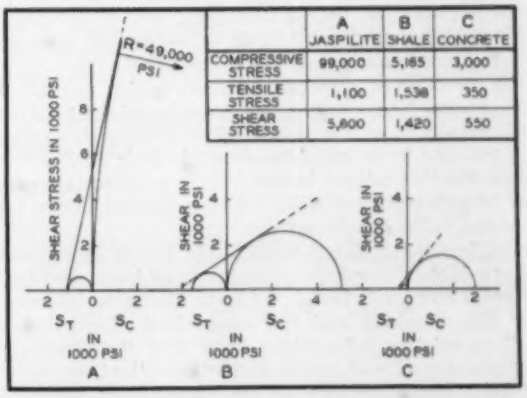


Fig. 2—Schematic Mohr's envelope of three materials. A—Material with equal compressive and tensile stress at failure. B—Material with unequal compressive and tensile stress. C—Soil (no tensile stress).

rock with the highest compressive strength whose tensile strength has been determined.[8] Its envelope has a fairly steep slope, although not the steepest one, as will be discussed below. Note also, that the tensile strength is less than the shear strength. Fig. 3B is the idealized Mohr's envelope of a shale from the roof of seam Danville No. 6 in Illinois. It has the least slope of all rocks listed in Table I and the shear strength is less than the tensile strength. A Mohr's diagram of concrete is also shown (Fig. 3C) for comparison.

In Table I some more evaluations of results of recent tests are given. Column 1 gives the source from which data has been obtained (see table notes).



	A JASPILITE	B SHALE	C CONCRETE
COMPRESSIVE STRESS	99,000	5,185	3,000
TENSILE STRESS	1,100	1,538	350
SHEAR STRESS	5,800	1,420	550

Fig. 3—Mohr's envelopes of rocks: A—Minnesota jaspilite. B—Illinois shale. C—Concrete, saturated 28 days.

Table I. Strength Data of Some Rocks

1	2	3	4	5	6	7	8	9	10	11	
Reference*	Type of Rock	Compressive Strength 10^3, Psi	Modulus of Elasticity (in Compression) 10^6, Psi	Tensile Strength, Psi	Modulus of Elasticity (in Tension) 10^6, Psi	Shear Strength, Psi	Equation of Mohr's Envelope	Ratio of Compressive to Tensile Strength	Ratio of Moduli of Elasticity (Compressive to Tensile)	Validity up to X, Psi	
										Point of Tangency	Safe Extrapolation
61.1 a	Chert (dolomitic), Tenn.	32.3	12.63	990	12.08	2900	$Y = 2900 + 2.8X$	32.6	1:1	1000	2000
61.1 b	Chert (See also jaspilite)	29.3	8.15	820	—	2550	$Y = 2550 + 3.0X$	34.7	—	750	1500
B 21	Coal (Upper Silesia)	2.8	—	—	—	750	$Y = 750 + 0.8X$	—	—	2800	3800
B 23	Coal (Cwmtillery)	1.6	—	300	—	200	$Y = 200 + 1.2X$	5.4	—	1900	2300
B 23	Coal (Barnsley, hard)	6.2	—	—	—	1600	$Y = 1600 + 0.8X$	—	—	1000	2000
42.2	Epidosite (mottled), Va.	49.9	13.7	660	—	3600	$Y = 3600 + 4.5X$	75.6	—	500	1500
1.3	Granite, Vt.	33.2	4.41(d)	1030	—	2900	$Y = 2900 + 2.8X$	32.2	—	900	1800
47.1	Granite (gneisses), Ga.	28.0	3.17	410	1.49	1720	$Y = 1720 + 4.2X$	68.3	2.13:1	400	1000
47.2	Granite (gneisses), Ga.	30.9	3.08	560	—	2100	$Y = 2100 + 3.6X$	55.2	—	500	1200
53.1	Granite, Colo.	25.5	3.94	590	—	2000	$Y = 2000 + 3.4X$	43.2	—	600	1300
55.2 a	Granite, Colo.	23.0	5.54	520	—	1850	$Y = 1850 + 3.6X$	44.2	—	500	1000
55.2 b	Granite, Colo. (parallel to bedding)	23.4	6.13	810	—	2200	$Y = 2200 + 2.7X$	28.9	—	800	1600
55.3	Granite, Colo.	25.3	3.94	500	—	1850	$Y = 1850 + 3.7X$	50.6	—	500	1000
51.2	Greenstone (amygdaloidal), Pa.	29.1	8.82	380	—	1700	$Y = 1700 + 4.5X$	76.6	—	350	800
P-5620-A	Greywacke (Sub), Calif.	7.9	1.8	700	—	1200	$Y = 1200 + 1.7X$	11.3	—	700	1400
8.4, B 28	Jaspilite, Soudan mine, Minn. (See also chert)	99.0	—	1100	7.28	5650	$Y = 5650 + 5.1X$	90.0	—	900	2000
1.2	Limestone (fossiliferous), Ind.	10.9	6.41(d)	522	—	1250	$Y = 1250 + 2.4X$	20.9	—	700	1400
59.1 a	Limestone (fossiliferous), Ohio	21.3	9.5	350	—	1320	$Y = 1320 + 3.9X$	60.8	—	300	600
59.1 b	Limestone (parallel to bedding)	26.1	8.75	1380	—	3050	$Y = 3050 + 2.2X$	19.0	—	1100	1800
1.1	Marble, Md.	30.8	7.15(d)	863	—	2650	$Y = 2650 + 2.9X$	35.7	—	800	1600
41.4	Marlstone, Colo.	25.0	4.17	480	4.2	1700	$Y = 1700 + 3.5X$	52.1	1:1	400	1000
B 33	Salt, Potash-, N. M.	4.2	—	402	—	650	$Y = 650 + 1.6X$	10.5	—	350	800
B 27	Salt, Rock-, Retsof, N. Y.	2.2	1.35	85	0.468	210	$Y = 210 + 3.2X$	25.8	2.9:1	400	800
1.4	Sandstone, Ohio	10.4	0.87(d)	120	—	560	$Y = 560 + 4.7X$	86.7	—	100	250
38.4	Sandstone, Pa.	14.8	2.0	230	0.29	900	$Y = 900 + 4.0X$	64.4	69:1	200	500
66.2	Sandstone, Pa.	12.6	1.2	130	—	680	$Y = 680 + 5.2X$	97.0	—	200	500
B 33	Sandstone (Pennsylvanian), Ill.	2.3	0.72	216	0.197	380	$Y = 380 + 1.7X$	10.6	3.7:1	200	500
61.2 c	Shale (carbonaceous), Tenn.	16.3	2.01	110	—	850	$Y = 850 + 7.7X$	148.0	—	200	500
B 33	Shale (carbonaceous), Ill.	5.2	1.09	1538	4.98	1420	$Y = 1420 + 0.6X$	3.4	1:2.2	1200	2000
59.3 b	Siltstone (wet, parallel-bedding), Ohio	5.0	12.6	440	—	750	$Y = 750 + 1.7X$	11.4	—	500	1000
B 32	Concrete	3.0	—	350	—	550	$Y = 550 + 1.6X$	8.5	—	300	600

* Unprefixed numerals refer to group numbers used by USBM for labeling samples. Numbers with prefix P indicate samples tested by U. S. Bureau of Reclamation, Denver. Those with prefix B refer to studies listed in the bibliography of this article.

Columns 3 to 6 are the results of determinations made by various investigators. Results of computations or graphical solutions are to be found in the remaining columns. Column 7 gives the values of shear strength obtained by graphical solution. Column 8 is the straight line expression of Mohr's envelope, $Y = C + \tan \phi X$, as previously detailed. Column 9 gives the ratio of compressive strength to tensile strength. They are identical with the blastability coefficient introduced by Hino[18] in his discussion of fragmentation by explosives. If the equation of Mohr's envelope is transformed by linear methods into the coordinates of the stresses S_1 and S_n, the equation of the principal stress relationship is obtained. This again is of the general type of a line with slope m and S_1 - intercept b, $S_1 = b + mS_n$. In this case the coefficient m of S_n is the ratio of compressive to tensile strength, which is Hino's blastability coefficient. This is explained in more detail in another paper.[24] Column 10 lists the ratio of the modulus of elasticity in compression to the one in tension. These values are reproduced for the sake of completeness. Column 11 gives a suggested range of validity in terms of the normal stress X. The first value in this column is equal to the point of tangency of Mohr's envelope with the compression circle; the second value is extrapolated.

It becomes evident from Table I that every rock has a Mohr's envelope typical only of itself, and that hardly ever will two rocks have the same intercept of the envelope and the same slope. Table I and other existing tabulations show that the measured shear strength of rocks under investigation varies from a maximum of 6340 psi (basalt from Medford, Ore.) to a minimum of 100 psi (a tuff from Oregon). *Eighty-four percent of the rocks investigated have a shear strength of less than 3000 psi.* Even the aforementioned jaspilite from the Soudan mine, with compressive strength as high as 99,000 psi and tensile strength of 1100 psi, has a shear strength of only 5650 psi. The equations of Mohr's envelope of rocks show furthermore that the slope ($\tan \phi$), which is the coefficient of internal friction, varies from 7.7 in the case of a carbonaceous shale from Tennessee (61.2c) to 0.5 in the case of a biotite schist from Colorado, (P-5089).

Of the great possible number of schematic Mohr's envelopes, one merits special discussion. This is the one for the case where tensile strength equals shear strength. The point at which the two strengths are equal is the theoretical border for the transition of a material from the brittle to the plastic state, or vice-versa. As Fig. 4 shows, this takes place at a slope of $\phi = 36.8°$, $\tan \phi = 0.75$, and a ratio of compressive to tensile strength of 4. If the slope of the envelope is steeper than this limiting case, the rock will tend to fail in tension—i.e., in brittle fracture. If the slope is less, the rock will yield to shear or ductile failure, because in this range the shear stress will always be less than the tensile strength and a material will always fail at its least strength.

While only one rock listed in Table I seems to fail in shear, this is due to the accidental choice of rocks. Numerous examples can be found in reports dealing with rocks from common U. S. oil formations. Hubbert and Willis[25], in discussing results obtained in triaxial testing of sedimentary rocks, many of which failed apparently in shear, state: "ϕ = angle of internal friction has values usually between 20° and 50° and most commonly not far from 30°." Handin and Hager,[12] in a critical study of the same work, assign the following angles of internal

friction to groups of rocks: (see Figs. 41 to 43 in ref. 12)

Rock Group	Angle of Internal Friction
Brittle	$> \phi = 45°$
Slightly ductile	$\phi = 25°$ to $43°$
Ductile	$\phi = 18°$ to $35°$

Many rocks tested by these researchers had an angle less than the critical angle of $\phi = 36.8°$. The reader should also be aware that this critical slope can intercept the shear axis Y at any value (in the case of the rocks tested until now, between 100 and 6340 psi).

Using straight-line expressions for the envelopes, the influence of confinement is not adequately taken into consideration. It is known from triaxial testing that with increased confinement and greater depth, all envelopes will tend to become more and more horizontal. In other words a rock which shows brittle behavior and tensile fracture when tested in a laboratory will finally fail in shear under sufficient confinement.

This ambiguous behavior of rocks should be considered when discussing the influence of strength on the behavior of brittle materials at failure. Transferring the results from tests of one rock to any other rock is bound to lead to unsupported conclusions. In the most common field of rock mechanics (roof control, comminution, drilling, and blasting) one very often finds strength properties proposed that are hardly of any significance in that particular type of testing.

Furthermore, too little consideration is given to the degree of confinement under which a rock is fractured in a particular operation. While, in the case of comminution, rocks can be assumed to be more or less independent of confinement, this is certainly not so with roof control and most cases of drilling and blasting. Up to now, however, most of our knowledge in these two fields comes from tests of small specimens studied at atmospheric pressure. In deep well drilling, as in well fracturing, there is almost complete confinement.

Having in mind a unified theory for the failure of a brittle material, the influence of shearing strength on the failure of rocks as induced by mining activities will be discussed.

Rock Failure in Ground Support: The case of rock failure in ground support will be treated first, in a very general way, by quoting Beringer[4]—the chapter on "Pressure Problems" as encountered on the Rand. He states: "The subject matter may be clarified if it be accepted that at different depths different problems will be encountered; here it might again be emphasized that sweeping statements generalizing on this or that type of support are distinctly out of place and misleading unless depth below surface be considered. In this manner it will be possible to discuss Pressure Zones . . ." He predicts that rockbursts, encountered from some 4000 ft to 6000 ft below surface, will be lessened in their intensity at 6000 to 8500 ft and that at the zone of ultra-deep mining, assumed at 8500 to 12,000 ft, "the rapid closure of the workings will approximate in principle to caving methods; rock bursts will be uncommon . . ." The similarity of these rock pressure phenomena with the modes of failures of rocks in the testing machine, and ranging from brittle to ductile fracture, is indeed intriguing.

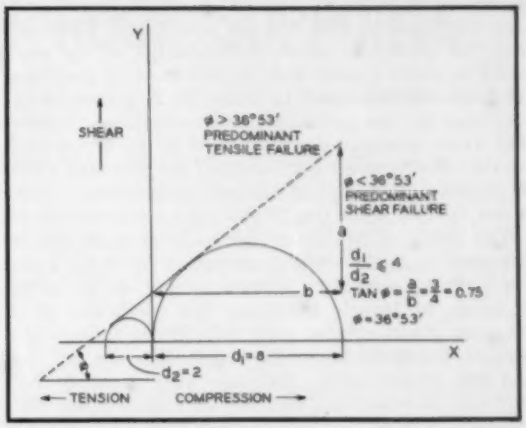


Fig. 4—Schematic Mohr's envelope of a rock with equal tensile and shear stress.

The ambiguous behavior of brittle materials is also shown by coal. While cubes of coal explode under uniaxial compression, they squeeze if the ratio of the width of a specimen to its thickness is increased above 5.0, or if moderate confining pressure is applied. It is therefore unrealistic to apply the data from the failure of a cube in the testing machine to the failure of a coal pillar underground. Holland[17] gives a most interesting discussion of past and present investigations and observations. However, he does not avail himself of more recent concepts of rock pressure when he concludes, from the fact that pillars did not fail, that "the maximum stress (in a pillar) does not reach as great a value as theoretical considerations and laboratory experimental methods indicate . . . The stress in the pillar walls would have been about 18,000 psi, yet the pillars showed little or no evidence of weight." He

Table II. Principal Stress Relationships of Some Coals*

Bibliography No.	Investigator	Type of Coal	Orientation of Sample Axis	Compressive Strength, Psi	Principal Stress Relationship	Validity Up to S_3 in Psi: Point of Tangency	Validity Up to S_3 in Psi: Extrapolated
21	Mueller	Upper Silesian	?	2800	$S_1 = 2800 + 6.6S_3$	1200	1500
23	Murrell	Cwmtillery	Bedding plane perpendicular axis, major cleat parallel axis	1550	$S_1 = 1550 + 5.14S_3$	1800	2300
23	Murrell	Barnsley, hard	Same	6210	$S_1 = 6210 + 4.8S_3$	2000	2200

* Resulting from graphical solution.

is apparently not aware of the increase of compressive strength of coal due to constraint. To check this, the principal stress relationships of the coals listed in Table I have been determined by graphical solution and are listed in Table II. A glance at the formulas for the principal stress relationship shows that at an assumed depth of 2000 ft the three coals would have reached a theoretical compressive stress of 16,000, 11,830, and 15,210 psi, respectively, which is not too far from the 18,000 psi postulated above.

The mode of failure of these three coals can be obtained from the data in column 8 of Table I and the limiting conditions shown on Fig. 4. If, in the equation of Mohr's envelope, the coefficient of X becomes equal or less than 0.75, shear failure will prevail. Coefficients of the three coals are 0.8, 1.2, and 0.8, respectively; they are very close to 0.75 and will become still smaller with increasing constraint. Coals will squeeze rather than fail abruptly as the unconfined compression test may have indicated.

Drilling: Rock mechanics in drilling depend on whether the rock is worn down by sliding abrasion, as in rotary drilling, or is chipped and crushed, as in percussion drilling. In many cases both principles are active, or are purposely combined as in rotary percussion drilling. Significant rock properties in any of the above cases range from shear strength, in the case of rotary drilling, to compressive (or impact) strength, in the case of percussion drilling. Merchant[20] in his study of the basic mechanics of metal cutting uses shear strength as the most influencing property. The mathematics of the theory of drilling were established in 1921 by L. Prandtl[23]. It was not until 30 years later that the application of his theory to the various types of drilling was studied by Kuehne[19] and Cunningham[8] The geometry of the chips obtained by Goodrich[11] checks very closely with those postulated by Prandtl. By his theory, similar values of shear strength correlate with similar geometry of the fragments. Goodrich comments on the fact that chip geometry seems to be the same regardless of material. The small spread of the values of shear strength listed in Table I might possibly explain this.

Blasting: The significance of rock properties seems to be better understood in the case of blasting. Two things take place if an explosive charge is fired at the bottom of a hole: 1) Gas pressure produces a relatively small zone of crushed rock near the explosion, the extent of which depends on the ratio of the amplitude of the compressive stress pulse to the compressive strength of the material. 2) Beyond the crushed zone the wave pulse travels outward in all directions losing its energy rapidly due to scattering and absorption.

No more fracturing would occur if not for the presence of free faces (tunnel face in the case of a horizontal blast hole, surface in the case of a vertical blasthole, well wall in the case of a fracturing process, or any discontinuity in bedded formations), all of which reflect the shock wave as a tensile stress and a shear stress pulse. As with most rocks, the tensile and shear strength are much less than the compressive strength, and much additional fracturing takes place.

The point of interest here is that in this theory the rock properties evidenced are the same as those used in the construction of Mohr's envelopes (See especially Fig. 4.) Hino's blastability coefficient[16, 10] is expressed for the unconfined state by the ratio of compressive strength to tensile strength (Table I, column 9). Fig. 4 shows that this ratio can be easily transformed into the coefficient of X in the equation of Mohr's envelope (Table I, column 8).

This paper is part of a comprehensive program in rock mechanics[10, 27, 31–34] undertaken by the Department of Mining and Metallurgical Engineering at the University of Illinois, Urbana. The wholehearted support given the project by T. A. Read, head of the department, is herewith gratefully acknowledged. Most of the computing, plotting, and preparation of the data for the manuscript was done by students R. J. Pusanik, A. Van Maele, R. K. Murray, and K. E. Wood.

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DEFLECTION OF MINE ROOF SUPPORTS

by LAWRENCE ADLER

Any design of a mine roof in bedded deposits which ignores differential deflections at the supports can quickly lead to dangerous overstressing. As illustrated by the typical case presented on page 1029, if one support deflects only 0.1 in. more than its neighbor, stresses 50 pct higher than anticipated will result.

Previous studies[1-3] have assumed that the mine roof acts like a beam clamped at both ends, with no deflection or slope[4] at the supports (Fig. 1). Essentially this assumes:[5,6] $\theta_A = \theta_B = 0$ and $d_A = d_B = 0$.

However, a host of conditions can cause differential sag or deflection at one support, and even an apparently trivial deviation can have major consequences in the beam: variations in spacing, size, and material of supports; local settlement due to floor heaving or lower mine openings; non-uniformity in wedging or bolt tensioning.[6] In one particular instance concrete pillars, poured in place, shrank away from the roof upon setting.[9]

When understood and controlled, differential sag becomes a definite advantage, permitting the transfer of loads from one support to another. Where one support is a bolt or prop and the other a pillar or rib, the load on the former can be reduced while the load on the pillar or rib is increased. This means two things: 1) savings can be effected by using smaller artificial supports such as props and bolts and 2) loads can be increased in the rib to induce eventual failure for longwall caving. In this last respect, another factor underlying coal bumps becomes understandable.

The design of a mine roof by beam theory assumes that when a bedded formation is homogeneous, isotropic, and elastic, it will act like a uniformly loaded beam, fixed or clamped at both ends,[6] as in Fig. 1.[10] These are important assumptions.

The uniform load is the weight of the beam itself or its body load. For a beam of unit width, this load becomes per foot: $w = \gamma h b$.

w = uniform load
γ = specific weight, lb per ft^3
h = depth or thickness of beam, ft
b = width of beam, ft

Since $b = 1$,

$$w = \gamma h \qquad [1]$$

A beam fixed at both supports is statically indeterminate to the second degree, that is, two equations in addition to those for static equilibrium are required to determine the reactions at the supports. These equations result from the geometry.

From statistics:

$$\Sigma F_y = 0\ ;\ R_A + R_B - wL = 0 \qquad [2]$$

$$\Sigma M_o = 0\ ;\ M_B + \frac{wL^2}{2} - M_A - R_B L = 0 \qquad [3]$$

Using superposition in which the left support is kept intact and the right one resolved into an active force and moment, we obtain from Fig. 2:[11]

$$\theta_B = \theta_{B1} + \theta_{B2} + \theta_{B3} = 0$$

$$\theta_B = \left(\frac{wL^2}{6} + M_B - \frac{R_B L}{2}\right)\frac{L}{EI} = 0 \qquad [4]$$

$$d_B = d_{B1} + d_{B2} + d_{B3}$$

$$d_B = \left(\frac{wL^2}{8} + \frac{M_B}{2} - \frac{R_B L}{3}\right)\frac{L^2}{EI} \qquad [5]$$

Where: Subscripts refer to position on axis of beam

R = force, lb
M = moment, ft-lb
w = uniformly distributed load, lb per ft
L = span, ft
θ = slope, radians
d = deflection, ft
E = Young's Modulus, lb per ft^2
I = Moment of inertia about the neutral axis, ft^4

Solving Eqs. 2 through 5 for the four unknown reactions, we obtain:

$$M_A = \frac{wL^2}{12} + \frac{6EI}{L^2}d_B \qquad [6]$$

$$M_B = \frac{wL^2}{12} - \frac{6EI}{L^2}d_B \qquad [7]$$

$$R_A = \frac{wL}{2} + \frac{12EI}{L^3}d_B \qquad [8]$$

$$R_B = \frac{wL}{2} - \frac{12EI}{L^3} \qquad [9]$$

Fig. 3 is obtained by plotting M_A and M_B vs d_B and then plotting R_A and R_B vs d_B and adjusting their scales to coincide with M_A and M_B vs d_B. It should be noted in Eqs. 6 and 7 that as d_B increases, M_A increases the same amount that M_B decreases. Eqs. 8 and 9 show a similar relationship between R_A and R_B.

Proof that M_A is the maximum absolute moment occurring in the beam is as follows:

$$+\circlearrowleft \Sigma M_X = 0$$

$$R_A x - M_A - \frac{wx^2}{2} + M_x = 0$$

where M_x = moment at x

$$M_x = -R_A x + M_A + \frac{wx^2}{2}$$

$$\frac{dM_x}{dx} = -R_A + wx$$

When

$$\frac{dM_x}{dx} = 0;\ x = \frac{R_A}{w}$$

$$\therefore M_x = M_{max} = M_A - \frac{R_A^2}{2w}$$

where M_{max} = maximum positive moment

Eqs. 6 and 8 into above:

$$M_{max} = -\frac{wL^2}{24} - \frac{72E^2I^2}{wL^6}d_B \qquad [10]$$

For small d_B: $M_A > M_{max}$

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TP 4816A. Manuscript, Nov. 20, 1958. AIME Trans., Vol. 214, 1959.

The absolute value of M_A is greater than the absolute value of M_{max}; consequently, M_A will be the basis of design, and M_{max} can be checked.

Comparison of the actual stresses, S, due to deflection with the assumed stresses, S_r (allowable modulus of rupture), for zero deflection is necessary.

$$M_A = \frac{wL^2}{12} + \frac{6EI}{L^2} d_B \qquad [6]$$

If $d_B = 0$: M_{A0} = maximum moment @ $d_B = 0$

$$M_{A0} = \frac{wL^2}{12} \quad \text{and} \quad L^2 = \frac{12\,M_{A0}}{w} \qquad [11]$$

Eq. 11 into Eq. 6:

$$M_A = M_{A0} + \frac{EIw}{2M_{A0}} d_B$$

$$\frac{M_A}{M_{A0}} = 1 + \frac{EIw}{2M_{A0}^2} d_B \qquad [12]$$

Since

$$S = \frac{Mc}{I} \text{ and } I = \frac{bh^3}{12} = \frac{h^3}{12}, c = \frac{h}{2}$$

$$S = \frac{6M}{h^2}$$

$$\therefore M = \frac{Sh^2}{6}$$

$$M_A = \frac{Sh^2}{6}; \; M_{A0} = \frac{S_r h^2}{6} \qquad [13]$$

Eqs. 1 and 13 into Eq. 12:

$$\frac{S}{S_r} = 1 + \frac{1.5E}{S_r^2} \gamma d_B \qquad [14]$$

That is: If the design is made on the basis of zero deflection, the ratio of actual stress to allowable stress is given by Eq. 14.

By substituting typical values into Eq. 14, the order of magnitude of S/S_r can be estimated.[15]

For sandstone:

$$E = 1.3 \times 10^6 \text{ psi}$$

$$\gamma = 0.0761 \text{ lb per in.}^3$$

$$S_r = \frac{640}{4} = 160 \text{ psi}$$

$$\frac{S}{S_r} = 1 + \frac{1.5 \times 1.3 \times 10^6 \times 0.0761}{160^2} d_B$$

$$\frac{S}{S_r} = 1 + 5.8\, d_B \qquad [15]$$

The S/S_r ratio is very high for even trivial values of d_B.

If $d_B = 0.1$ in. into Eq. 15,

$$\frac{S}{S_r} = 1.58$$

The actual stress is over 50 pct more than the allowable, a very significant increase.

This means that whenever deflection can not be calculated, it is best to strive for zero deflection. All supports should be kept as uniform as possible in size, material, and spacing. Where this can not be done, as when supports are adjacent to ribs and pillars, these variables should be adjusted to minimize the differential deflections. Where there are lower workings, supports should be aligned directly above one another. Floor heave should be carefully observed to prevent unsafe conditions in the roof. Maximum and uniform pre-stressing of bolts and props is necessary and must be maintained.

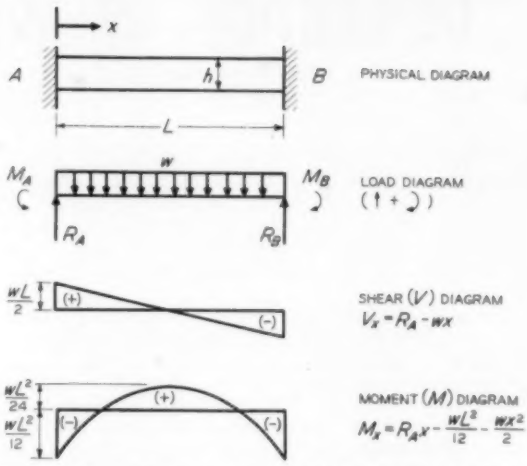

Fig. 1—Properties of a beam with both ends built in.

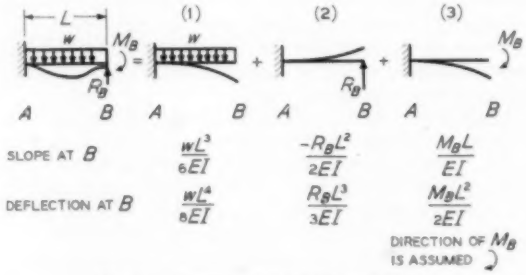

Fig. 2—Components of deformation.

When a deflection d_B is known to occur, the roof span L should be calculated on the basis of Eq. 6 and checked by Eq. 10.

An advantage can be obtained in certain cases by permitting controlled deflection through the use of crush blocks. In coal mining, no attempt is made to support the main roof by props;[16] the roof is permitted to deflect and crush the blocking without impairing the structural integrity of the props and their ability to support the immediate roof. When the immediate roof itself is still not loaded to its allowable stress, additional deflection of the crush blocks will reduce the load on the props while increasing the stress in the roof. (See Eqs. 6 through 10). If the span is predetermined, and is less than the allowable span, the problem is most easily solved by use of Fig. 3, which is accompanied here by a sample problem. When more than one adjacent support deflects, the solution must be repeated from span to span.

Conversely, as R_B decreases R_A increases. Sufficient increase in R_A can lead to conditions suitable for longwall caving by stressing the face toward failure as applied to coal mining. The particular situation should be analyzed with reference to the procedure presented here, rather than by blind use of the equation, since they themselves contain the assumed restriction $\theta_B = 0$. Fig. 4 illustrates this roof action.

Conclusion: When a mine roof is designed for maximum safe span, it is usually assumed that the

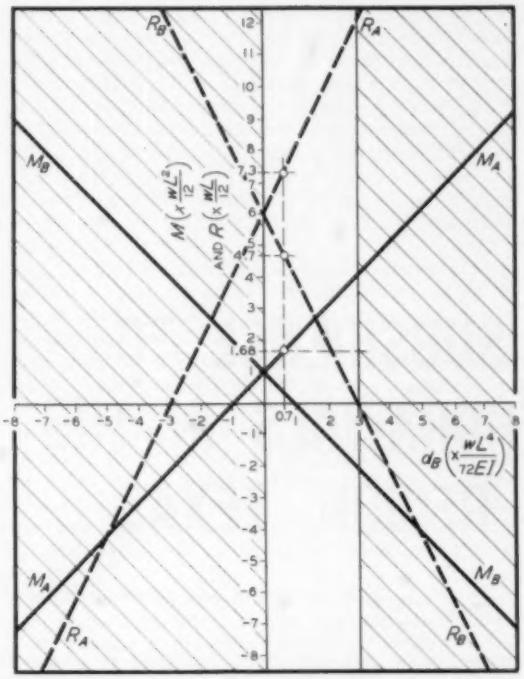

Fig. 3—Moment and reaction vs deflection, with both ends built in. Since d_B->O and R_B->O, values cannot exist in shaded areas. Sample problem at right.

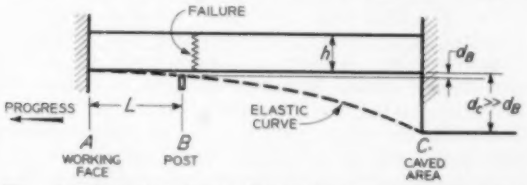

Fig. 4—Elements of roof during longwall caving. Both supports B and C deflect, but since d_c>>d_B, roof failure will occur as illustrated above. Working face A is loaded by wL/2 and additionally by the deflection at B.

differential deflection of the supports is zero. However, should an apparently insignificant deflection exist, stresses in the roof can quickly exceed the allowables. Consequently, where these deflections are indeterminate, strong measures should be taken to minimize them and if possible to make them zero.

When a mine roof is designed for some convenient lesser span, controlled, permissive deflection will result in lower loads on the props or bolts.

A corollary action increases the load on the other support. If this is the rib, conditions favorable to longwall caving can be induced in the working face.

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SAMPLE PROBLEM

$E = 1.3 \times 10^6$ psi, $\gamma = 0.0761$ lb per in.^{3} } Sandstone

$S_r = \frac{640}{S.F.} = \frac{640}{4} = 160$ psi

$S.F.$ = Safety factor = 4

h = bed thickness = 3 ft

L = existing roof span = 25 ft

$w = \gamma h$

M_{all} = allowable moment in roof

M_{ex} = existing moment in roof

$$S_r = \frac{M_{all}C}{I} : M_{all} = \frac{Sr\,I}{C} = \frac{160 \times 144}{1.5}\left(\frac{3^3}{12}\right)$$

$$= 1728 \times 20 \text{ ft-lb}$$

$$M_{ex} = \frac{wL^2}{12} = \frac{0.0761 \times 1728 \times 3 \times 625}{12} = 1728 \times 11.9 \text{ ft-lb}$$

$$\frac{M_{all}}{M_{ex}} = \frac{20}{11.9} = 1.68$$

$$M_{all} = 1.68\,M_{ex} = 1.68\left(\frac{wL^2}{12}\right)$$

Through

$M = 1.68\left(\frac{wL^2}{12}\right)$ draw a horizontal line as shown. Any moment below this value is permissible. If it is desired to load the roof up to the allowable moment, draw a vertical line at the intersection of this horizontal line and M_A. Its abscissa of 0.7 $\left(\frac{wL^4}{72EI}\right)$ gives the permissive differential deflection of support B or d_B. The intersection of this vertical line $d_B = 0.7\left(\frac{wL^4}{72EI}\right)$ with R_A, and R_B, represents the load at these supports, in this case 7.3 $\left(\frac{wL}{12}\right)$ and 4.7 $\left(\frac{wL}{12}\right)$ respectively.

Therefore:

$$d_B = 0.7\left(\frac{wL^4}{72EI}\right) = 0.7\left[\frac{0.0761 \times 1728 \times 3 \times 25^4}{72 \times 1.3 \times 10^6 \times 144\left(\frac{3^3}{12}\right)}\right] = 0.00356 \text{ ft}$$

$d_B = 0.0428$ in.

$$R_A = 7.3\left(\frac{wL}{12}\right) = 4.7\left(\frac{0.0761 \times 1728 \times 3 \times 25}{12}\right) = 6000 \text{ lb}$$

$$R_B = 4.7\left(\frac{wL}{12}\right) = 7.3\left(\frac{0.0761 \times 1728 \times 3 \times 25}{12}\right) = 3880 \text{ lb}$$

With

$d_B = 0$:

$$R_A = R_B = \frac{wL}{2} = \frac{0.0761 \times 1728 \times 3 \times 25}{2} = 4940 \text{ lb}$$

which not only gives the load transferred from B to A, but also checks the result, since: $4940 = \frac{6000 + 3880}{2}$.

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RELATION OF LAND SUBSIDENCE TO GROUND-WATER WITHDRAWALS IN THE UPPER GULF COAST REGION, TEXAS

by A. G. WINSLOW and LEONARD A. WOOD

Subsidence has occurred in several areas of the upper Gulf Coast region of Texas, although in most cases this is not evident without precise instrumental leveling.

As referred to in this report, the region comprises about 7200 sq miles of the Gulf Coastal Plain and includes all or parts of the following counties: Harris, Fort Bend, Waller, Brazoria, Galveston, Liberty, Chambers, Orange, and Jefferson (Fig. 1). Topographic relief is low, ranging from sea level at the Gulf of Mexico to 300 ft or more in northwestern Harris County.

In this upper Gulf Coast region, which embraces the most heavily populated and industrialized parts of Texas, industrial and municipal water supply is obtained chiefly from wells. Largest center of ground-water withdrawal is the Houston-Baytown area, where about 200 million gallons per day was pumped in 1956 for municipal and industrial use. Other large centers of ground-water withdrawal include the Alta Loma sector and the heavily industrialized Texas City area in Galveston County, where about 23 mgd was pumped in 1956. In the Freeport area in Brazoria County about 6 mgd was pumped in 1956 for city and industrial supply.

In addition to withdrawals in metropolitan districts, great quantities of ground water are supplied by irrigation wells to thousands of acres of rice. These wells are widely dispersed over many miles, principally in Harris, Waller, Fort Bend, Brazoria, and Liberty counties, and effects of pumping are not so readily noticed as in the industrial and metropolitan sectors.

Subsidence: Starting with the 1905-1906 line from Smithville, Tex., to Galveston, the U. S. Coast and Geodetic Survey has extended a network of first and second-order level lines throughout the upper Gulf Coast region. In 1918, when a line was run from Sinton, Tex., to New Orleans, La., a tie was made to the 1905 leveling at Houston. In 1932-1933 a line was run from Palestine, Tex., to Houston, and a good deal of leveling was carried out in the vicinity of Houston. At this time the entire network was adjusted to the Sea Level Datum of 1929.

In 1935-1936 and 1942-1943 several new lines were run and considerable releveling was performed. Supplementary adjustments were made after both the 1936 and 1943 levelings in order to reduce the elevations to the Sea Level Datum of 1929. These adjustments probably masked some of the subsidence that had occurred up to that time, although a certain amount of subsidence was noticed in the 1943 leveling.

When several lines in the vicinity of Houston and Galveston were releveled in 1951, the regional nature of the subsidence became apparent.[1] Direct comparison with the 1943 leveling was possible because the datum was not changed. Comparisons with prior leveling were unreliable because of differences in the early and subsequent datums.

In 1953-1954 many lines in the region were releveled and in 1957 the entire network, including the elevations previously determined, was readjusted to determine the changes in elevations as indicated by various levelings between 1905 and 1953-1954. In this instance the adjusted elevations were held fixed near the boundaries of the region where the bench marks seem to have remained stable. The only sea-level connection held fixed was the connection of the 1905 leveling to the 1903-1906 tidal series at Galveston.

Almost the entire region has been at least slightly affected by the subsidence, some areas to a great extent. The profiles of subsidence (Fig. 2) and the map showing the contours (Fig. 3) illustrate both regional and local changes.

A large area of subsidence is centered in the Houston-Baytown district, where the maximum recorded is about 2.7 ft between 1905 and 1954. This probably falls short of the actual maximum, since land surface subsided as much as 2.5 ft in the industrial section alone between 1943 and 1954. Sub-

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sidence in the Houston-Baytown area as a whole has been on a rather broad scale; in only a few localities do great variations occur within short distances. For this reason there is little visible surface evidence. In several places, however, particularly in the industrial section, certain features can be attributed to subsidence. In some instances deep-set well casings protrude from the ground where the land surface has subsided. In others there is surface evidence of faulting which may be related to subsidence.

The Texas City area has experienced more local subsidence than the Houston-Baytown vicinity (Figs. 2 and 3); both profile and contour map reveal great differences in the amount that has occurred within short horizontal distances. This differential subsidence has had visible results in the immediate vicinity of Texas City—protruding well casings, clogged sewers, and broken pipelines. Maximum subsidence along the line of profile (Fig. 2) has been about 3.5 ft between 1905 and 1954, but this line does not run through the industrial section, where even greater amounts have occurred. Industrial representatives in the area report a total of more than 4 ft.

Another subsidence center in the upper Gulf Coast region appears to be the Beaumont-Port Arthur-Orange area, where there is a concentration of industry. The total here is probably not as great as in the Houston-Baytown or Texas City sectors; however, there is a rather large area in which the land surface has subsided at least 0.25 ft in the years 1918 to 1954. During the same period about 1 ft of local subsidence took place in this area in the immediate vicinity of Spindletop oil field.

Another small area is centered at Freeport, where there is a concentration of industry and groundwater withdrawal from shallow sands. Subsidence here has been on a small scale; a maximum of about 0.5 ft was recorded during the perid 1943-1951. Record of earlier subsidence at Freeport is not available.

Geology and Hydrology: The upper Gulf Coast region of Texas is underlain by a thick sequence of unconsolidated fresh-water-bearing sands, sandy clays, and clays. Geological formations comprising the aquifers include the Lagarto clay of Miocene (?) age, the Goliad sand of Pliocene age, the Willis sand of Pliocene (?) age, the Lissie formation and the Beaumont clay, both of Pleistocene age. The formations consist largely of alternating beds of sand and clay; most individual beds are lenticular and not persistent over great distances.

Some of the formations consist predominantly of sand, others predominantly of clay. The Lagarto is principally clay but contains layers of sand, mostly fine to medium-grained.

The Goliad and Willis sands and the Lissie formation are not distinguished in the subsurface and are generally referred to locally as *Lissie*. The so-called *Lissie* is largely sand, which occurs primarily as discontinuous lenses interbedded with clay. The *Lissie* is the principal aquifer in the Houston area.

The Beaumont clay is composed of two members —the *Alta Loma* member and the upper member. The Alta Loma is primarily a massive sand bed,

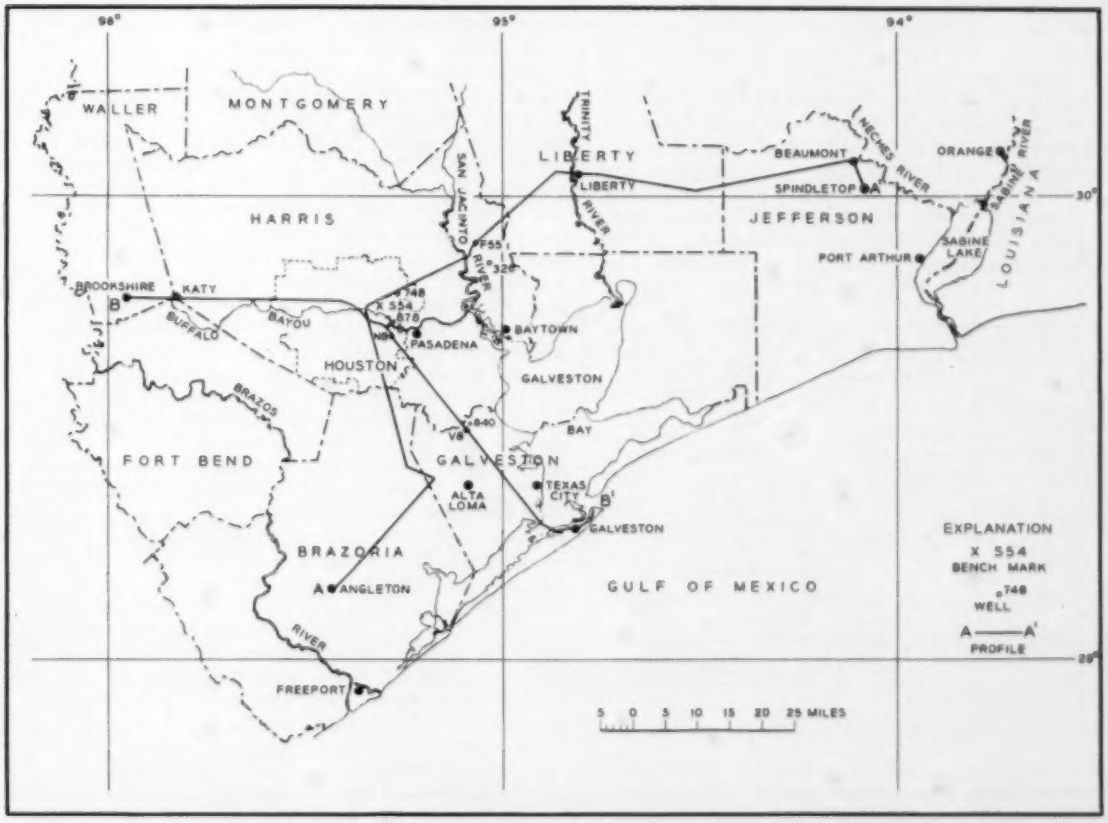

Fig. 1—Map of the upper Gulf Coast region, Texas. Subsidence of selected bench marks is shown in Fig. 5.

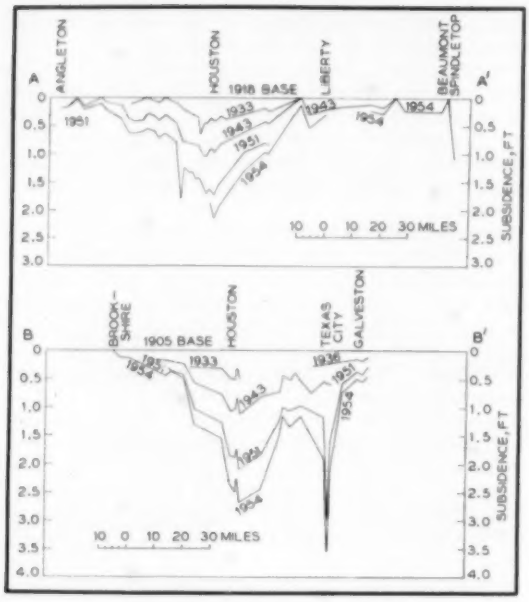

Fig. 2—Subsidence of the land surface along the lines A-A' and B-B' in the upper Gulf Coast region of Texas, 1953-1954. Locations of profiles are shown in Fig. 1.

though it does have a few clay layers. The most persistent single sand bed in the region, it can be traced from Freeport to the Louisiana line. It is the main aquifier in Galveston County, southeastern Harris County, and Orange County.

The upper member of the Beaumont clay consists chiefly of clay but contains thin lenticular beds of sand, most of it fine-grained. This member supplies comparatively large quantities of water to municipal and industrial wells in the Texas City area.

Geologic structure of the region is relatively simple. The formations crop out in bands roughly parallel to the coast and dip gently toward it. The older water-bearing beds dip 20 to 30 ft per mile; the younger ones may dip less than 10 ft per mile. The beds are disrupted locally by salt domes, some more than a mile in diameter, which nearly reach the surface in several places. No large-scale faulting has been observed in the younger beds, but there are many small-scale faults.

Although the principal water-producing zones in the upper Gulf Coast region are more or less distinct locally, they are all in hydraulic connection and regionally may be considered as a unit. Movement of water through the aquifer before groundwater withdrawals began has been described as follows (Ref. 2, p. 388): "Water moves from the intake areas down the dip of the beds, and when it passes beneath a confining layer (bed of lower permeability) artesian conditions are established. As soon

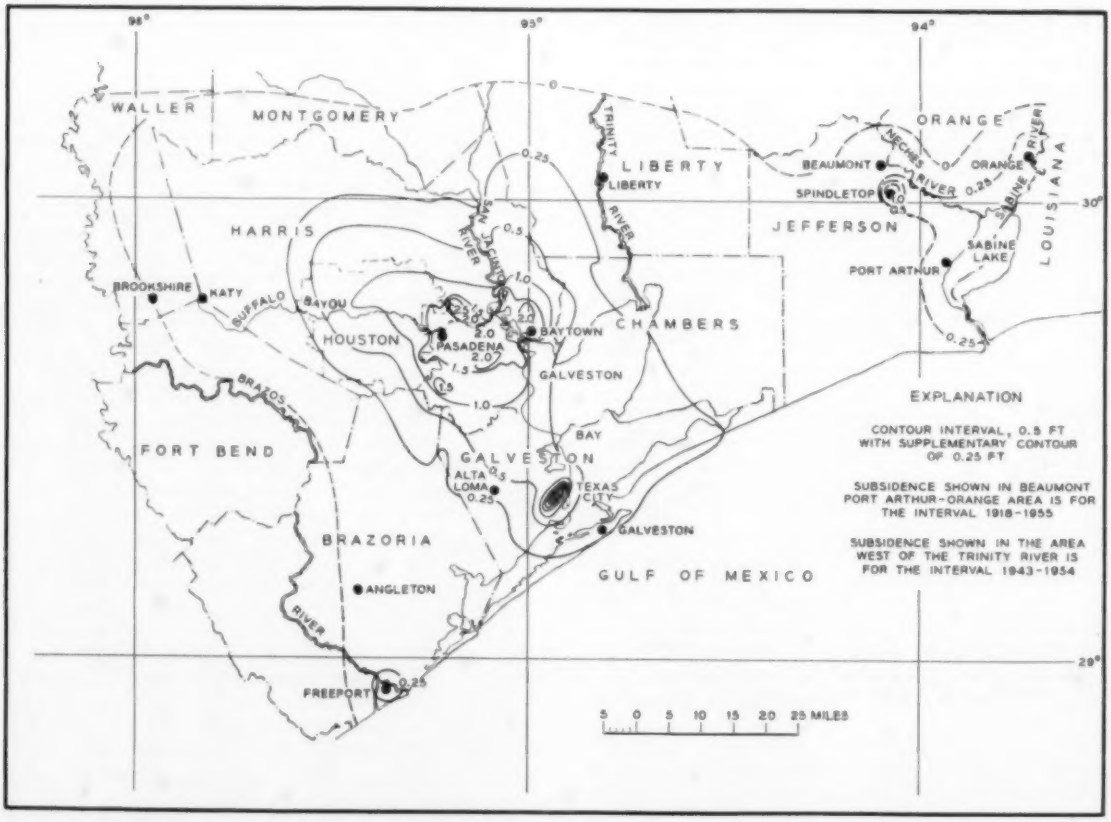

Fig. 3—Subsidence of the land surface in the upper Gulf Coast region of Texas during the period 1943-1954.

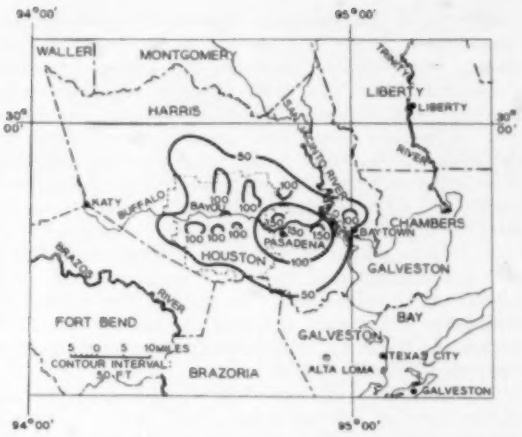

Fig. 4—Decline of artesian pressure head in the Katy-Houston-Pasadena-Baytown area of Texas, 1943-1954.

as these conditions occur, water will move upward through the clays (or beds of lower permeability) as well as laterally through the sands although . . . the vertical movement will be at a much lower rate than the lateral movement." Under such conditions both a vertical and lateral pressure gradient will be established and water will ultimately be discharged at land surface. The artesian pressure provides a buoyant effect that helps to support the aquifer (Ref. 3, p. 458).

Development of large ground-water supplies and consequent lowering of artesian pressure in the upper Gulf Coast region has disturbed the natural hydraulic gradients in the aquifer. Some sands have been pumped more heavily than others, and because of differences in permeability and the remoteness of hydraulic connection, pressure heads in different sands now vary greatly with depth. Fig. 4 shows the decline in artesian pressure head in the most heavily pumped sands in the Houston-Baytown area during the period 1943-1954; this is a composite of the decline in many individual sands, as most of the observation wells are screened in several.

Ground-water withdrawals in Harris County have been concentrated in three districts: 1) the Pasadena-Baytown area, where the water has been used mostly for industry; 2) the Houston area, where it is used chiefly for municipal purposes; and 3) the Katy rice-irrigation sector. In the Pasadena-Baytown district industrial demands have led to the concentration of wells within short distances, causing excessive water-level declines—especially in the vicinity of Pasadena, as shown in Fig. 4. In the Houston sector withdrawals have been largely from Houston's municipal wells, which are fairly well distributed throughout the city. This has resulted in more widespread and uniform decline of water levels than in the Pasadena-Baytown area. In the Katy rice-irrigation area the wells are even more widely dispersed and declines are less.

Although most ground-water withdrawals in Harris County have been from the *Lissie*, in the Baytown area and southeastern part of the county and in Galveston County the principal aquifer is the Alta Loma sand member of the Beaumont clay. In the Alta Loma area of Galveston County the development was started in 1898. Since that time water levels have declined some 150 ft, mostly prior to 1945.

In the Texas City area the principal aquifer is now the upper part of the Beaumont clay, but before 1948 larger quantities of water were pumped from the Alta Loma sand member. Problems relating to encroachment of salt water and the land-surface subsidence in the Texas City area resulted in partial abandonment of the Alta Loma as an aquifer in that locality when surface water was made available in 1948. This raised the Alta Loma water levels, which previously had dropped considerably. Continued withdrawals from the upper member of the Beaumont clay have lowered levels in that part of the aquifer, but in recent years the rate of decline has been very slow.

Withdrawals in the Beaumont-Port Arthur-Orange area have been concentrated largely in the Alta Loma sand, but declines in water levels have not been great. Considerable amounts were formerly withdrawn from the Beaumont-Port Arthur sector, but practically all the wells in that vicinity have been abandoned because of the encroachment of salt water. Most of the ground-water withdrawal at present is in the Orange district.

Causes of Subsidence: Land-surface subsidence caused by removal of ground water or other fluids has been observed in many places, and the mechanics of the processes involved have been investigated. Meinzer (Ref. 4, p. 90-93) states that in an artesian system the artesian pressure helps support the framework of the aquifer and that when the artesian pressure is lowered water is released from storage in the aquifer and the beds are compacted. He says also (Ref. 3, p. 458) that most of the compression takes place in the finer-grained materials. Tolman (Ref. 5, pp. 328-329) states that where an aquifer is confined by slightly permeable beds, the reduction in pressure heads in the sands will create a hydraulic gradient from the confining beds toward the sand and water will move slowly from the slightly permeable beds into the sand.

Poland and Davis (Ref. 6, pp. 294-295) have summarized possible causes of subsidence as follows: 1) loading at land surface, 2) vibrations at or near land surface, 3) compaction due to irrigation and farming, 4) solution due to irrigation, 5) drying out and shrinking of deposits, 6) oxidation of organic

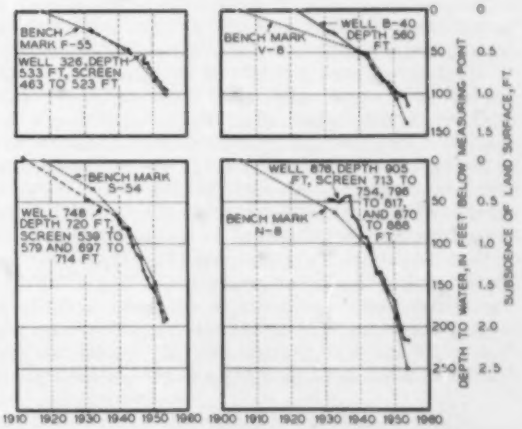
BENCH MARK F-55
WELL 326, DEPTH 533 FT, SCREEN 463 TO 523 FT
BENCH MARK V-8
WELL B-40 DEPTH 580 FT
BENCH MARK S-54
WELL 748 DEPTH 720 FT, SCREEN 539 TO 579 AND 697 TO 714 FT
BENCH MARK N-8
WELL 878, DEPTH 905 FT, SCREEN 713 TO 754, 796 TO 817, AND 870 TO 888 FT
DEPTH TO WATER, IN FEET BELOW MEASURING POINT
SUBSIDENCE OF LAND SURFACE, FT
1910 1920 1930 1940 1950 1960
1900 1910 1920 1930 1940 1950 1960

Fig. 5—The subsidence of selected bench marks compared with the decline of artesian pressure head in nearby wells, upper Gulf Coast region of Texas. The locations of wells and bench marks are shown in Fig. 1.

material, 7) lowering of water table, 8) decline of pressure head in confined aquifers, 9) decline of pressure in oil zones due to removal of oil and gas, and 10) tectonic movement.

The first six of these possible causes of subsidence probably do not apply in the upper Gulf Coast region of Texas. Lowering of the water table is quite possibly one of the contributing causes of subsidence in the region, but direct evidence of this is lacking. An obvious case of subsidence caused by decline of pressure in oil zones due to removal of oil and gas is furnished by the profile at Spindletop (Fig. 2). Land-surface subsidence has been observed in other oil fields in the region, and subsidence in the Goose Creek field in eastern Harris County has been described by Pratt and Johnson.[7]

Tectonic movement may be a cause of subsidence, since obvious displacement has been noted along some of the many small faults known to exist in the region. It is not clear, however, whether the displacement is the result of strictly tectonic movements or whether the faulting is related to subsidence in the region due to removal of ground water or other fluids.

The principal and certainly most obvious cause of subsidence in the upper Gulf Coast region of Texas is the decline of artesian pressure head. Fig. 5 shows a remarkable coincidence between graphs of subsidence of individual bench marks and graphs of decline in water levels (artesian pressure head) in nearby wells. In the Houston area the ratio of approximately 1 ft of subsidence to 100 ft of decline of artesian pressure head has remained fairly constant throughout the period of record. In the Texas City area the ratio is greater.

Further evidence of relation between subsidence and decline of artesian pressure head is afforded by comparison of Figs. 3 and 4. Resemblance of the two maps is apparent. Subsidence has centered in the industrial area near Pasadena where the artesian pressure head has declined the most, becoming less at great distances from the area of large pressure declines in the industrial sector.

Relation of Volume of Subsidence to Volume of Ground Water Withdrawn: When the fine-grained materials in the fresh-water-bearing section compact, the volume of pore space lost by compaction is equal to the volume of subsidence. The volume of water yielded from storage in the clays can be determined by computing the volume of subsidence (1 ft of subsidence yields 1 ft of water). The data needed to compute accurately the volume of subsidence in the upper Gulf Coast region are not available; however, an approximate volume for part of the region can be determined from the subsidence contours in Fig. 3. An estimated 3.4×10^{10} cu ft of subsidence took place between 1943 and 1954 in that part of the region influenced by ground-water withdrawals in the Katy-Houston-Pasadena-Baytown areas. During the same period about 114×10^{10} gal was withdrawn from wells in the same area. Converting the volume of subsidence to gallons of water (3.4×10^{10} cu ft $= 25.4 \times 10^{10}$ gal), it can be seen that 25.4 or about 22 pct of the water pumped in the

$$\frac{}{114}$$

Katy-Houston-Pasadena-Baytown area represents water that had been stored in the fine-grained materials. Quality and quantity of data preclude an exact answer, but 22 pct is believed to be of the correct order of magnitude.

Effects of Subsidence: Continued land-surface subsidence in the region has had and will have certain undesirable effects. In the Texas City area structural difficulties have already occurred—protruding well casings, broken pipelines, reversed flow in sewage lines, and cracked foundations. In the Houston-Baytown area, where the process has been more on a regional scale, there have been comparatively few problems of this kind that can be attributed definitely to subsidence of the land surface, but in places where well casings have failed and foundations and highways have cracked, subsidence may have been the cause. The threat to structures throughout the area has been a matter of concern to industry, and plans for construction have been modified acordingly.

Another effect of subsidence has been lowering of land in the coastal areas. Part of the Baytown district once used for grazing is now tideland. In the Texas City area some of the land formerly believed high enough above sea level to be safe from hurricane tides is now subject to inundation during hurricanes.

The few effects that might be considered beneficial should be mentioned. About one fifth of the water made available to wells in the region has been freed from the fine-grained materials as the land subsided, obviating the need for greater pumping lifts. Furthermore, subsidence has centered in the Houston ship channel area, deepening the channel so that less dredging is required.

The question of first importance in any discussion of the subject is what is going to happen in this region in the future. Subsidence will probably continue indefinitely even if ground-water withdrawals are not increased, because the head in the shallow sands will continue to decline as it adjusts to the lower heads in the deeper sands. Reasonably accurate quantitative predictions of the future of subsidence in the region will require a much better knowledge of the causes and mechanics and the actual details of what is happening in the region. More research and collection of basic data are needed. The U. S. Coast and Geodetic Survey has proposed releveling every five years in this region, but the most important lines should be releveled more often, and additional level lines should be installed.

This report is based on data obtained during ground-water investigations made by the U. S. Geological Survey in cooperation with the Texas Board of Water Engineers and the cities of Houston and Galveston.

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THE ELECTRONIC COMPUTER AND STATISTICS FOR PREDICTING ORE RECOVERY

by ROBERT F. SHURTZ

The author proposes a method used with some success on a magnesite deposit at Gabbs, Nev. He believes this procedure to be more sound than the blind practice of assigning uniform quality to large, sometimes vast blocks or ore on the basis of analyses made of a small number of samples.

When an ore deposit is evaluated on the basis of core sampling, questions always arise as to how much weight should be given the various sample grades and how the deposit should be divided into specific volumes assigned to corresponding grades. For a tabular deposit it is customary to use the so-called *zone-of-influence*. This zone is usually defined as the polygon in the plane of the deposit having corners halfway between a given core drill intersection and each of the nearest neighboring intersections. The volume of the ore in this polygon is assigned the analysis obtained from the drill core taken at the intersection. In massive or irregular deposits, volumes of various shapes may be defined with respect to the locations of drill core samples. These volumes may be regarded as three-dimensional zones-of-influence; the theory involved in assigning the values of the central analyses to the ore in the volumes is the same as that used in the case of a tabular deposit.

The zone-of-influence method was used in evaluating one of the magnesite deposits at Gabbs, Nev.[1-3]

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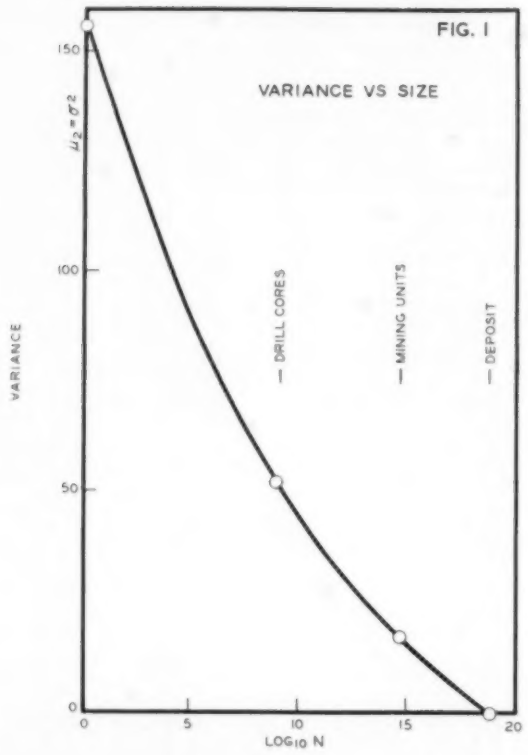


Original estimates of ore tonnages falling in the various ranges of quality were based on almost 5000 analyses of core samples from about 100 core drillholes. On the basis of this drilling a pit was designed for mining as much of the magnesite as possible without removing an excessive amount of the dolomite irregularly surrounding the deposit. The pit was then divided into horizontal benches 10 ft thick for mining. Each bench was subdivided into 100-ft squares and each square assigned the average grade of the drill intersection it contained. There were one to four intersections in each square, usually less than four. The concentrations of both lime and silica were considered in making the early estimates, although later experience has shown that control of the silica is relatively easy. For this reason the following discussion will be limited to the problem of lime concentrations.

Early experience in mining this deposit selectively showed that recovery of high-grade magnesite ore was substantially less than the proportion of high-grade ore calculated from the core-drilling results. Since it was known that this reduced recovery could not be attributed to poor operation in the quarry, a method was sought that would correct the estimates of ore tonnages falling within the desired ranges of quality.

At first a correction was made by calculating an experience factor equal to the ratio between the amount of each grade of ore recovered and the amount of the corresponding grade of ore estimated from the core drilling results. However, it was believed that the factors so derived could not be applied with confidence to the whole deposit, since their values must certainly depend heavily on the grade and distribution of ore in the first portion removed by mining. That portion happened to be of substantially lower grade than the average estimated for the whole deposit. It was suspected, therefore, that the experience factor for high-grade ore was smaller than it should be and that if this factor were applied to the whole deposit the total proportion of high-grade ore would be seriously underestimated.

Alternative methods of estimating the distribution of reserves in the deposit were carefully investigated. Almost from the start, it was clear that the difficulty lay in the great variability of magnesite ore quality over short distances in the deposit. The vertical core drillholes, for the most part spaced roughly on a 100-ft square lattice, were obviously too far apart to provide accurate direct information on the proportion of ore falling within various ranges of quality. The blastholes, drilled on 6.5-ft centers, provided accurate data on this point, but this information differed radically from that obtained from the core drillholes. This divergence is believed due to the fact that sampling is systematic with both kinds of drillhole and therefore heavily dependent on the interrelation between drillhole spacing and distances in the deposit over which quasi-periodic variations of quality may occur.[4] Preliminary consideration of various methods showed that accurate correlation of the two sets of drillhole data, though possible in principle, would be highly complicated and expensive to compute.

The most forthright attack on this problem, and one that illustrates the principles involved, would be a two-dimensional harmonic analysis of variation in the quality of each horizontal bench in the ore deposit, based on analyses of drill cores taken from that bench. However, such an analysis would necessitate simultaneous solution of a set of equations containing as many variables as there are drillholes through the bench. Since the number of holes is about 100 and the proposed quarry contains more than 40 benches, it is readily seen that a truly formidable amount of computation would be involved.

Harmonic analysis would contemplate the variations in quality as being due to periodic variations above and below the average quality of ore in a particular bench, and it is instructive to consider how the analyses from holes at large spacings are related to analyses from holes at smaller spacings in such a model of the quality variations. The periodic variations are regarded as sine and cosine waves of various lengths and amplitudes so oriented on a given bench that the positive and negative contributions of all these waves at any point added algebraically to the average lime concentration will approximate the lime concentration at that point on the bench. As the lengths of these waves are rational fractions of the linear dimensions of the bench, they do not require evaluation, that is, waves having lengths of 1/2, 1/3, 1/4, etc. of the linear dimensions of the bench must be considered. The number of these waves which can be summed together in a harmonic analysis is, therefore, equal to the number of observations of lime concentration made in the bench in question, that is, as great as the number of holes intersecting the bench in question. Although in the present instance this number is high enough to offer an appalling computation problem, it still is not sufficient to represent accurately the amplitude of the short waves when the initial long-period terms of the series are evaluated by the use of assays from the coreholes, which are spaced for the most part on 100-ft centers. However, analyses

from these holes could be used to evaluate an arbitrary group of the short-period terms selected as being most important on the basis of geologic considerations such as the spacing of joints, etc. In view of the uncertainties involved this was not carried out, even though it would have been interesting to see how the results came out.

Attention was also given the possible use of auto-correlation coefficients between successive analyses along the vertical lengths of the drillholes, a scheme resembling the one proposed and employed by H. J. de Wijs.[6] If auto-correlation could be found in the cores over vertical distances of some substantial number of feet, it might be reasonable to assume that high-grade ore extended for about an equal distance from the location of an intersection. This plan, and modifications of the same idea, was abandoned because geologic considerations showed that variation in quality over vertical distances in the deposit bears little or no resemblance to the variation over horizontal distances.

Consideration of the interdependence between sample sizes and the distribution of samples into quality ranges led finally to development and application of the procedure detailed in this article. To summarize briefly in advance, it may be pointed out that samples of individual mineral grains from the deposit would distribute themselves into only two classes of quality represented by the pure minerals magnesite and dolomite, since dolomite is the principal lime-bearing mineral involved. On the other hand, samples comparable in size to the size of the deposit itself would necessarily cluster very closely around the average lime concentration for the whole deposit, which is about 6.5 pct CaO. Therefore, as the size of the samples is continuously increased, there should be a transition from a bi-modal frequency distribution having all samples clustered at the ends of the range of quality between magnesite and dolomite to the uni-modal distribution with all samples clustered closely around the average. Discontinuities in this clustering tendency will be present because the samples are assumed to contain integral numbers of mineral grains. However, when samples containing as many as several hundred grains are considered, it is legitimate to treat the frequency distribution of samples over this range—from 0 to 30.4 pct lime—as being substantially continuous. Therefore, in discussing the interrelations between quality distributions in samples of drill core and in larger samples, it seems reasonable to regard the tendency toward clustering as being continuous.

It will be argued in the following discussion that this tendency is closely related to the clustering that would be observed in averaging the lime concentrations in groups containing equal numbers of drill core samples drawn at random from all the core samples actually taken from the deposit. In some respects this is similar to the relation between the probability of drawing a single ace in a poker hand and the probability of drawing 2, 3, or 4 aces, which is much less than that of drawing a single ace. A method will be proposed for evaluating this reduced probability of finding high-grade ore. That is to say, using the analogy of aces, it will be determined whether the probability relationship between a high-grade piece of drill core and a mineable unit of ore is most like the corresponding relationship between one ace and two, one ace and three, or one ace and four. An empirical method for determining this relationship using an electronic computer will be described, as well as an analytical method using procedures available from the theory of statistics.

It is of considerable incidental interest to note that a quantitative measure can be placed on the reduced probability and that the reciprocal of this measure can be used to indicate the efficiency of the selective mining procedures employed. This reciprocal can serve as a sort of precision constant for evaluating the effect of changes in mining practice.

Reducing the Variance: The foregoing comments have all been of a general and qualitative nature. We now proceed to illustrate quantitatively how the clustering effect described above can be expected to take place as the size of samples is increased and how this effect can be evaluated.

A reasonable quantitative measure for this clustering tendency must be selected. The variance, s^2, of a group of samples is often used for this purpose; for reasons that will soon be apparent it is also convenient to use it here. The variance for a group of analyses is computed by finding the average lime concentration for the group and then finding all the differences between this average and the concentrations of lime in the individual samples. The sum of the squares of these differences is the variance. It may readily be seen that all the differences, and the hence the variance, will be small when the concentrations of lime fall closely around the average concentration, whereas the differences and variance will both be large when the concentrations of lime differ greatly from the average. With reference to an earlier statement that the distribution of lime analyses from individual grains would consist of two groups of values at 0 pct and 30.4 pct lime, whereas the distribution of lime analyses from very large samples would cluster near the average value of 6.5 pct, it becomes plain that the variance must undergo an overall decrease as the size of the samples increases.

When a great many analyses are available, it is customary to group them into grade intervals in order to simplify calculation of both the average, m, and the variance. Standard texts[6, 7] on statistics give short cuts for accomplishing this, so only the fundamental formulas need be given here:

$$m = \frac{1}{n} \sum_{1}^{n} f_i x_i \qquad [1]$$

Table I. Observed Frequencies

Grade Interval	Range, Percent CaO	Designed Pit	Mined Ore
0	0 to 2	134	89
1	2 to 4	68	73
2	4 to 6	38	43
3	6 to 8	30	24
4	8 to 10	17	10
5	10 to 12	20	25
6	12 to 14	14	13
7	14 to 16	10	14
8	16 to 18	8	14
9	18 to 20	6	3
10	20 to 22	2	8
11	22 to 24	8	6
12	24 to 26	6	4
13	26 to 28	6	7
14	28 to 30	12	23
15	30 to 32	7	18

$$s^2 = \frac{1}{n} \sum_{i}^{n} f_i (x_i - m)^2 \qquad [2]$$

In these equations x_i is the value of the lime concentration at the midpoint of a grade interval and f_i the number of concentrations falling in that particular interval. The mean or average value for the lime concentration is represented in Eq. 1 by m and the variance in Eq. 2 by s^2.

It is of interest to calculate the means and variances to be expected in the distributions of lime concentrations from hypothetical samples of extreme sizes taken from the deposit in question. The value for the average lime concentration, m, has been determined to be very close to 6.5 pct. In the extreme case in which samples are taken consisting of the whole deposit less one grain of mineral, there are as many possible samples as there are grains in the deposit and all these samples will show lime concentrations exceedingly close to 6.5 pct. Whatever number of samples might be taken, the values of $x_i - m$ in Eq. 2 are so small as to make the value of s^2 come out at zero for practical purposes.

On the other hand, in samples consisting of single grains of mineral, these grains must, as already mentioned, be either of dolomite or magnesite. Since 78.6 pct of the deposit consists of magnesite and 21.4 pct of dolomite (excluding for present purposes the presence of other minerals), for any single grain picked at random the probability will be 0.214 that it is dolomite and 0.786 that it is magnesite. In 1000 such samples the expected numbers of dolomite and magnesite grains will be 214 and 786 respectively. The mean of this distribution can be verified by calculation with Eq. 1 as follows:

$$m = \frac{1}{1.00} [(0.214 \times 30.4) + (0.786 \times 0.00)] \qquad [3]$$

$$m = 6.5 \text{ pct CaO}$$

The variance comes out as:

$$s^2 = \frac{1}{1.00} [(0.214 \times 23.9^2) + (0.786 \times 6.5^2)]$$

$$s^2 = 155.4 \qquad [4]$$

Column 3 of Table I lists 384 lime analyses selected from the total of several thousand by a random procedure to be described later. Substituting the values from Table I for the f_i in Eq. 2 and using the percentages of lime at the midpoints of the grade intervals for the x_i, the variance of this frequency distribution may be calculated to be 51.9.

The three values just calculated for the expected variances of the distributions for examples of various sizes may be related to the sizes themselves. For this purpose, size of sample may be expressed in terms of the number of mineral grains it contains. Thus for samples of size 1, the variance is 155.4. The whole deposit is estimated to contain 5.95×10^{13} grains averaging 150 mesh, and the expected variance for samples approaching this size is 0. The core samples differ somewhat in size, but the average may be taken as a 5-ft cylinder of 2⅛-in. diam containing about 1.27×10^5 grains. The variance for the lime concentration in samples of this size is 51.9. In Fig. 1 these three pairs of values are plotted as a curve showing the variance of expected distribution as a function of the logarithm of sample size.

Taking into account the methods adopted for the quarry at Gabbs, it can be estimated roughly that a 30x30x10-ft ore block is the smallest size that can be mined selectively. Such a block contains about 4.19×10^{11} mineral grains. When this point is also plotted in Fig. 1, it is observed that the variance of distribution of the lime concentrations in samples of this size may be expected to be about 17. The ratio between the variance expected from drill core samples and the variance expected from mineable units is therefore approximately 3.1. This value is only a rough estimate, but because the abscissa is on a logarithmic scale it is not very sensitive to variations in the estimated size of the mineable unit.

It is now in order to show how the distributions of samples of different sizes may be related to one another in a wider sense. If, in the case of the magnesite deposit under consideration, it had been determined in advance that the mining method would not be capable of selecting units of ore smaller than 30x30x10 ft, a sampling system for evaluating the proportion of blocks of this size in various ranges of quality could have been used. A reasonable way to have done this would have been to select areas 30 ft square either at random or systematically in the area covered by the deposit and to sample each of these areas with a cluster of n drillholes. Quality of the 30x30x10-ft blocks stacked under each of the sample areas could have been evaluated by averaging the analyses of the drill cores from each sample block. The blocks in the stacks could then have been taken as a sample representing the total population of blocks of this size forming the deposit. However, the totality of core samples taken in this manner would be expected to have a quality distribution very like the one observed from the holes that were in fact drilled, i.e., the distribution of Table I. The expected relation between this distribution and the distribution of averages for the blocks described above will now be discussed.

In the first extreme case, the deposit may be regarded as comprised of core-sized pieces distributed at random. The distribution of the averages of n analyses of cores taken from each block can then be visualized easily by using a card-drawing model. Assume that an ace represents a core containing 1 pct lime, a deuce represents a core containing 2 pct lime, and so on. If n (in the previous paragraph) were equal to 3, a 30x30x10-ft block having 1 pct lime would be represented by a drawing of three aces. A block containing 2 pct lime would be represented by draws of ace-deuce-three or ace-ace-four with either combination in any order. These events are much less likely than the drawing of single aces or deuces. Statistics provide an exact method for handling such computations by use of characteristic functions.[8] It will suffice here to note that the characteristic function for the distribution of averages from the n analyses of our example is the nth power of the characteristic function for the distribution of the individual analyses.

$$\phi_n(t) = [\phi(t)]^n \qquad [5]$$

The variance of the distribution of the averages, $\frac{S_n^2}{n}$, is:

$$\text{Var}\left(\frac{S_n^2}{n}\right) = \frac{s_n^2}{n} \qquad [6]$$

Other higher order moments of the distribution of averages are obtained by similar simple equations.

On the other hand, if the core analyses from a volume as small as an individual block are not independent of one another this simplicity disappears. If, however, there is perfect correlation among the lime concentrations in the cores from each block, a new type of simplicity appears. Mathematically perfect correlation requires that the correlation coefficients, r_{jk}, between all possible pairs of lime concentrations taken from a group of n cores in a 30x-30x10-ft volume in the deposit are all equal to 1. In this ideal second extreme case, all the cores from each block would have the same lime concentrations and the distribution of the lime concentrations for the blocks would be identical with that for the cores. The characteristic function of the distribution of the blocks is then identical with that of the distribution of cores to the first power instead of the nth power and the variance of the former distribution is equal to that of the latter divided by 1 instead of n as in Eq. 6.

The latter case can also be represented by a card-drawing model in which we imagine a sequence of 13 packs of cards each consisting entirely of cards of a single denomination with the packs arranged in order of the denominations and a fourteenth pack which is normal. The first card of the desired group of n cards is drawn from the normal pack and the remaining n-1 cards are drawn from the mth deck of the 13 stacked decks where m is the denomination of the first card drawn from the normal pack. Obviously the distribution of groups in this case will be identical with the distribution of single cards in the normal deck, just as the lime concentrations from the cores and the blocks in the hypothetical example were identically distributed.

It is here assumed that the relation in any actual ore deposit will fall somewhere between the extremes just described.

The essential idea is that the characteristic function of the distribution of blocks is estimated to be equal to some power of the characteristic function of the distribution of cores. For the moment, we are assuming that we know nothing about the characteristic function or the distribution function beyond the observed frequencies shown in Table I. However, for any n we can find the distribution function corresponding to the nth power of the characteristic function by drawing enough groups of n samples from the distributions of Table I to form a new distribution of average lime analyses for the n-fold groups. This is what was actually done for 1000 groups of 2, 3, 4, and 5 members each for core distributions from the mined portion of the deposit and from the deposit as a whole. Comparison of the amount of high-grade ore as mined with the amounts shown on the distributions derived for the mined ore for various values of n permitted interpolating a value for n. This value was used to interpolate between the derived distributions for the deposit as a whole in order to find an estimated distribution of mineable units in the deposit.

Before any further discussion of this estimate, details of the sampling procedure will be given.

Data Selection and Reduction: In view of the labor involved in making other statistical investigations not dealt with in this article, it was desired to reduce the number of analyses used. Therefore, 414 analyses were selected from the several thousand available by a random procedure to be described. The drawing was made in two groups of 207 samples each. The frequency distributions of lime analyses for these two groups were compared by means of the chi-squared test. Without giving details of this comparison, it can be stated that agreement was satisfactory. Both groups of analyses were then combined for further work. As was expected, some of the core locations selected at random fell in areas where rhyolite dikes or other types of intrusive rocks were found. These samples were rejected, leaving a total of 384 samples.

Table II. Derived Frequency Distributions Designed Pit

Grade Interval	Percent CaO	Cum. Freq.	Individual Frequency				
			n = 1	n = 2	n = 3	n = 4	n = 5
0	0 to 2	360	360	216	126	85	38
1	2 to 4	538	178	196	245	221	182
2	4 to 6	641	103	176	203	198	263
3	6 to 8	721	80	123	147	181	220
4	8 to 10	767	46	83	90	156	147
5	10 to 12	821	54	60	89	70	77
6	12 to 14	858	37	58	36	39	31
7	14 to 16	883	27	44	33	35	19
8	16 to 18	906	21	18	14	11	7
9	18 to 20	923	17	8	10	2	3
10	20 to 22	929	6	5	6	1	1
11	22 to 24	950	21	3	—	—	1
12	24 to 26	967	17	3	—	—	—
13	26 to 28	983	16	1	—	—	—
14	28 to 30	994	11	3	—	—	—
15	30 to 32	1000	6	2	—	—	—

Even though the samples were selected at random from the population of drill cores available, the locations of the core drillholes themselves are not at random. To avoid over-representation of certain portions of the deposit in which the drillholes are systematically more closely spaced, the area of the deposit was divided into sub-areas each 100 ft square; when there was more than one core drillhole in a square, one of the holes was selected at random to represent it.

The depths of the core drillholes from the surface to their intersection with the wall or bottom of the planned pit were divided by 50 and the integer nearest the result of this division was used as a weighting factor for that particular hole to assure that samples from that hole would have a probability of being drawn in rough proportion to the depth. In order for this to be done, a table of the numbers of the holes was prepared in which each number was entered a number of times equal to the weighting factor. This produced a table having 241 entries, which were assigned serial numbers from 0 to 240, 250 to 490, 500 to 740, and 750 to 990. Each entry had four numbers; for example, 1, 251, 501, and 751 all corresponded to the second entry in the table.

A table of six-digit random numbers was used to select entries from the table of drillhole numbers and to select simultaneously a depth from the corresponding drillhole. To do this, the first three digits of the six-digit number were used to select the entry in the table of drillhole numbers. If these first three digits comprised a number not entered in the table, e.g., 247, that random number was discarded and the next random number used.

The depth in the drillhole so selected at which the analysis should be taken was determined by the last three digits in the six-digit random number. If these last three digits formed a number greater than the depth of the hole within the designed pit, then

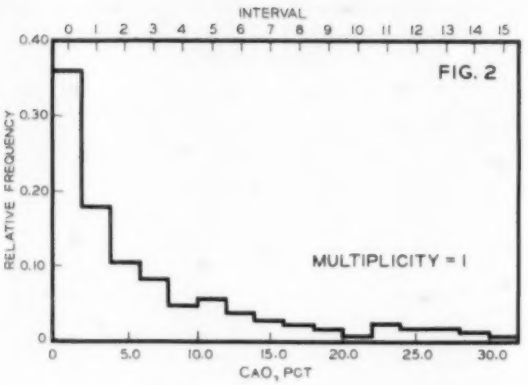


FIG. 2

the depth of the hole was divided into the last three digits and the remainder was used as the depth from which the core sample was selected. Many other ways can be proposed for carrying out the selection process although, in spite of the apparent complexity, the writer and his assistant required only one afternoon to select and tabulate the 414 analyses.

Many of these same core drillholes passed through a portion of the deposit from which well over a million tons of rock had already been mined. The magnesitic core drill samples from this portion of the deposit numbered 374. In view of this small number, the whole population of core samples for the quarried portion was used.

Table I shows the distribution into grade intervals of the two groups of samples thus far described. It will be observed that there is a marked tendency toward the appearance of a second maximum in the range from 28 to 31 pct lime. This secondary maximum is caused by the incursion into the pit of substantially pure dolomite which can easily be discarded during mining. Therefore, when the frequency distributions were recalculated to a base of 1000 samples, the secondary maxima at the dolomitic end of the range were eliminated by extrapolation of the smooth curves through this range of concentrations. In the actual calculation of reserves, the total tonnage of rock to which the derived frequency distribution was finally applied was reduced in proportion to the number of samples discarded by this smoothing process. The result of these operations is shown in Table II in the fourth column under $n=1$.

Computation of Derived Distributions: The cumulative frequencies of Table II were all punched in each of a group of 1000 Remington-Rand cards in preparation for computing the derived distributions. The lime concentrations at the midpoints of the grade intervals were wired on the plug boards for the Univac-60 on which the programs were run. A lead card containing a random number having eight digits was sent through the computer at the beginning of each run. A total of eight runs was required to produce the twofold, threefold, fourfold, and fivefold averages for each of the two distributions of samples. A different random number was used, of course, on each of the eight lead cards.

The computer was programmed to develop its own 'random numbers using Lehmer's method," starting from the number on the lead card for a given program. The cumulative frequencies punched on each of the program cards were range-tested by subtraction from the first three digits of the random number then in storage in the computer. When a negative result was found, the percentage of lime appropriate to that range of cumulative frequencies was accumulated in the storage for lime percentages and the number 1 was accumulated in the cycle-counting storage. The computer then range-tested the accumulated number in the cycle-counting storage to determine whether the multiplicity for that program, 2, 3, 4, or 5, had been reached. If it had not, the computer calculated another random number, selected the approximate range of frequencies, accumulated the number corresponding to the percentage of lime, accumulated another unit in the cycle-counting storage, and range-tested again for multiplicity. When the desired multiplicity had been reached, the accumulated percentage value for lime from the several steps was divided by the number of cycles to produce an average. The average was punched in the card and then in the computer, and the whole operation was repeated on the next card. The averages for all four multiplicities were punched in each card by changing the location of the punch output between programs.

For the high multiplicities as many as 160 separate steps were required on a single card, so the computer worked much more slowly than usual. Even so, only about one working day of computer time was necessary. Some additional time was required on the tabulating machine to assemble the averages from the cards.

There is nothing novel about this procedure, which is a common variation of the class called *Monte Carlo methods*. The computer program has been discussed here only to demonstrate the principle involved and to assist those who may wish to attack similar problems. It is obvious, for example, that with a probability of 1 in 1000, the first three digits of a truly random number may be any number between 000 and 999. To illustrate the computation procedure described, the 538 to 641 frequency range (Table II) corresponding to the number of analyses in the grade interval between 4 and 6 pct lime will have 103 chances in 1000 of being selected in any given cycle. This is equal to the probability of finding in the deposit a core sample having a lime concentration between 4 and 6 pct. The average lime concentration in this range is very near 5 pct. Thus, during the programs, the computer was in effect drawing random groups of n lime concentrations with the same probability that the concentrations occur in drill cores.

The same result would be obtained by writing 5 *pct* on 103 slips of paper and the other average lime concentrations on the numbers of slips shown

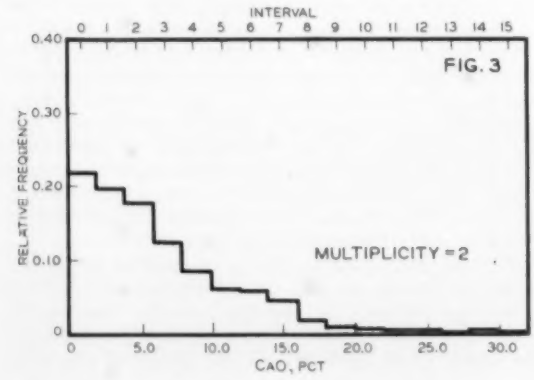
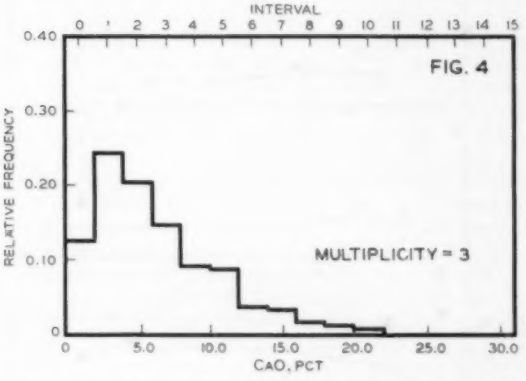


FIG. 3

opposite the corresponding ranges in Table II under $n=1$. The total number of slips would then be 1000. All of these could be shuffled together and dealt, for example, into piles of five slips each. The numbers on the slips could then be averaged. When 1000 such averages had been obtained in this way, the distribution of these averages would be very like that shown for $n=5$ in Table II. This procedure would be unpleasantly time-consuming but by no means an impractical substitute when a computer is not available.

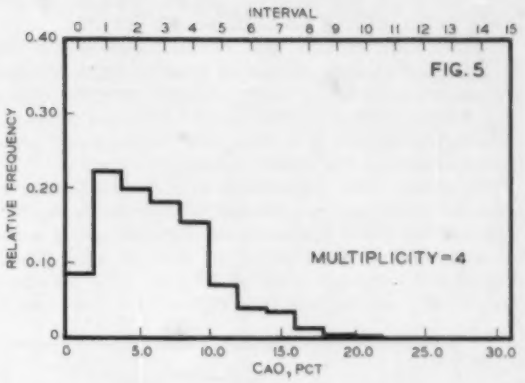
The derived distributions for the several multiplicities, which are all based on the observed distribution for the designed pit, are shown in Table II under appropriate values of n. In Figs. 2-6, the histograms representing these distributions, the gradual tendency toward increased clustering around the average lime concentration at 6.5 pct is obvious. Variances for the distributions for n (multiplicity) = 1, 2, 3, 4, and 5 are 51.96, 25.88, 17.84, 14.12, and 11.12 respectively. These should be 51.96, 25.98, 17.32, 13.24, and 10.39 in strict accord with the inverse relation to n set forth in Eq. 6.

The derived distributions based on the observed distribution for the mined portion of the deposit are



not detailed here. The only use made of these consisted of calculating from them the expected proportions of ore averaging 2 pct lime. An accurate record of the proportion of ore of this grade which was actually recovered was available for comparison with the proportions on the derived distributions in order to determine the estimated value for n.

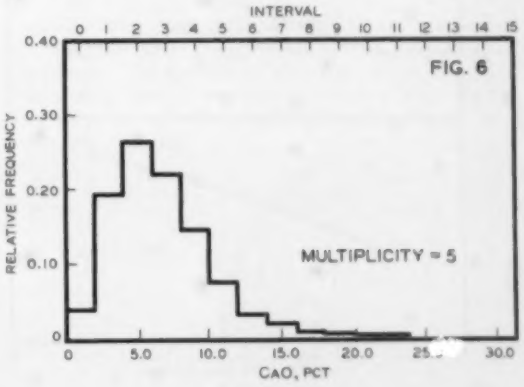
The lower portion of Fig. 7 shows how n was determined graphically. The curve labeled *Pit 9-1-56* is drawn through the five points showing the relative frequencies of samples from the observed distribution ($n=1$) and from the derived distributions ($n=2$, 3, 4, or 5) for ore mined before Sept. 1, 1956. The points are for the 0th grade interval, which includes lime concentrations from 0 to 2 pct. The upper curve labeled *Designed Pit* is drawn through the relative frequencies for this interval taken from Table II. The rapid decrease in the frequency of averages in this interval with increasing n strikingly illustrates the main argument being made here. The smoothing practiced is deemed warranted by the random fluctuations that appear as a result of the limited number of samples drawn by the computer and the irregularities in the observed distributions. The proportion of ore averaging 2 pct lime is taken as being double the proportion averaging 1 pct lime, which is that ore falling



in the 0th interval. This statement is not true for $n=1$ because there is not an equal or larger amount of ore averaging 3 pct lime to average with the higher-grade ore in this case. However, discussion in the present instance will not be concerned with values of n near 1.

The proportion of ore actually mined in which the lime concentration averaged 2 pct was 0.14. Therefore, a value for the multiplicity should be selected which will yield a proportion of 0.07 of ore in the 0th interval for the derived distribution for mined ore. When this is done as shown in Fig. 7, the estimated multiplicity turns out to be 3.2, in good agreement with the crude value previously obtained by much more general reasoning. This suggests that the crude approach described under *Reducing the Variance* may be useful in the absence of other data, although more experience with its use and a liberal application of good judgment are desirable.

Turning now to the other grade intervals, the variations of the estimated proportions of ore in these intervals are shown in Figs. 7, 8, and 9. In each case, the average lime concentration is equal to twice the interval number plus 1, a convention needed for later discussion. The estimated proportion of ore in the 3 pct lime grade interval remains fairly constant over the range of multiplicities investigated, while the proportions for the intervals from that for 3 pct lime up to that for 13 pct lime increase with multiplicity as an expression of the tendency to group around the average. Still higher intervals show the decreases to be expected at the ends of the range of concentrations. By taking the ordinates of these curves at $n = 3.2$, it is possible to find the final interpolated derived distribution for the deposit. This is shown in Fig. 10 as a cumula-

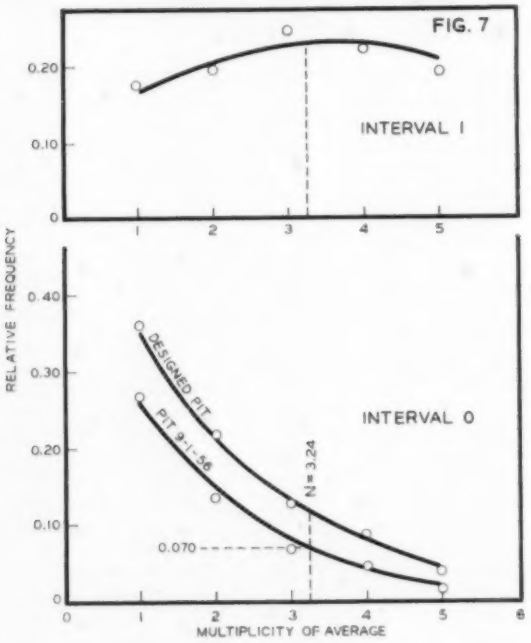


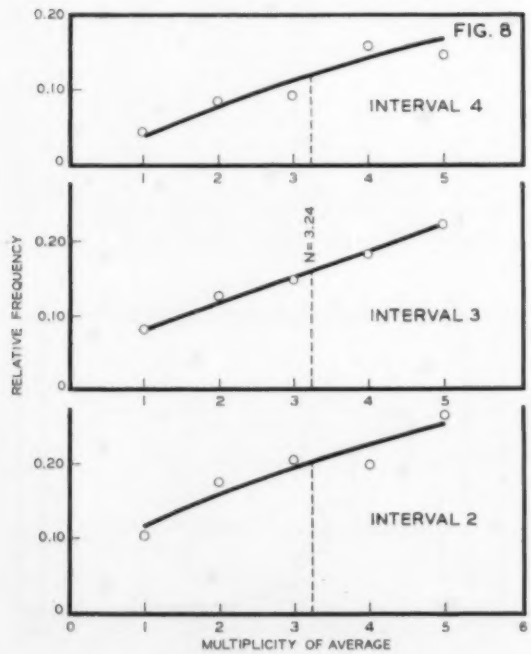
tive curve for ore of lower grades than the high-grade direct mining ore containing 2 pct lime.

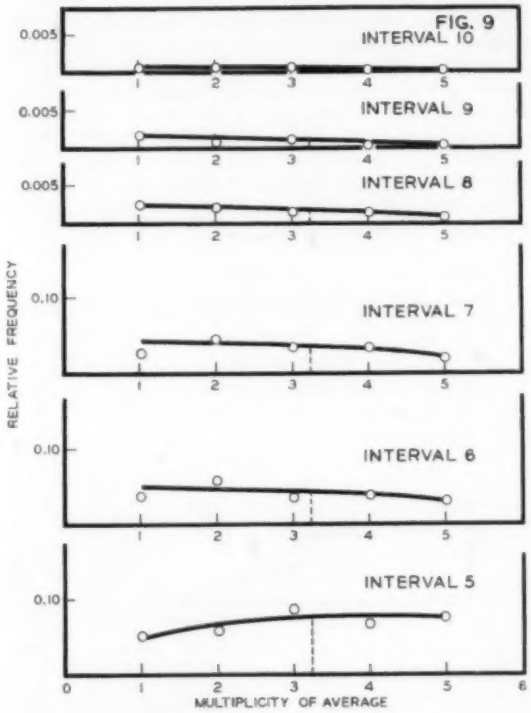
This completes the task of distributing the ore in this deposit into ranges of quality by a method that is believed to be more realistic and theoretically more sound than the commonly used zone-of-influence methods. It is time now to point out some consequences of the theory advanced here.

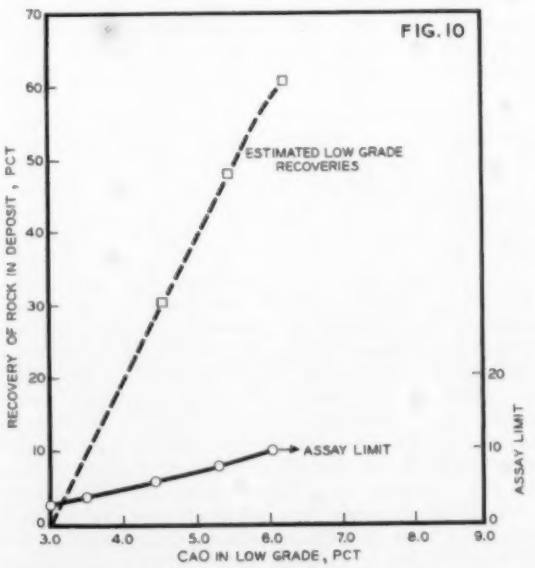
Discussion: The importance of reducing the variance in evaluating this deposit springs from the fact that the standard deviation of distribution is large as compared to the ranges of quality into which output from the pit is to be divided. The standard deviation is the square root of the variance, and it is often used to express quantitatively the spread of a frequency distribution. Dimensions of standard deviation are the same as those of the mean, in this case, percent lime. In the simple case of the normal frequency distribution, 68.269 pct of the observations will be expected to lie within one standard deviation of the mean, 95.450 pct within two standard deviations, etc., cf. Cramer.[10] For other distributions, similar but less accurate limits can be set using the Bienaymé-Tchebychef inequality.[11]

In the present instance, the important dividing line between direct mining ore and beneficiating ore occurs on the low side of the average quality of the deposit. Therefore, as the variance and hence the









standard deviation are reduced, the clustering toward the average that must occur—unless the mining method is precise enough to distinguish between drill-core sized pieces—*moves ore upward* toward the average and out of the relatively narrow high-grade range. This, of course, increases the estimate of beneficiating ore available, although this is hardly a blessing.

The estimated amount of beneficiating-grade ore in this case is also augmented by the fact that ore *moves down* toward the average from the high-lime ranges. This occurs because the dividing line at about 10 pct lime between low-grade ore for direct use and waste is well on the high side of the average, so that the proportion of this grade is also increased over the expectation suggested by the unadjusted distribution of drill cores.

It is interesting to see how reduction of the variance and standard deviation of the distribution of assays for a metallic ore, say copper, might affect recovery in mining. Let it be assumed that the mean concentration of copper is 0.5 pct and the standard deviation of assays 0.1 pct. If the assay limit is 0.3 pct, the range of concentrations in samples accepted as ore runs from 0.3 pct upward. This range includes the average concentration, so reduction of variance resulting from the limited selective power of whatever mining method is used will be expected to concentrate the concentrations of copper observed during mining even more strongly in the range acceptable as ore. As standard deviation in this case is relatively small, the concentration effect will not be very important. For example, assuming a normal distribution of assays in the statistical sense, the number of samples having copper concentrations below 0.3 pct may be taken as equal to the proportion of the area of the normal distribution lying below the mean minus twice the standard deviation. This proportion is only 2.3 pct. If the reduced variance for mineable units is estimated to be one half the variance for samples, the standard deviation will be 0.071. Now the assay limit lies 2.82 standard deviations below the average and only 0.3 pct of the mineable units may be expected to be waste. The difference is not important.

However, if the standard deviation had been 0.3 pct, amounts of waste would have been estimated at 25.2 pct and 17.5 pct for samples and mineable units, respectively, under the assumptions made in the preceding paragraph. This phenomenon accounts for the fact that such deposits, which have average concentrations above the assay limits, often produce more ore than is originally estimated.

Now let it be supposed that the cut-off assay is 0.6 pct, that the mean concentration is at 0.5 pct, that the standard deviation for samples is 0.3 pct, and that the assay distribution is again represented reasonably by a normal curve. Now only 37 pct of the deposit is ore when calculated by use of the unreduced variance. If the mining method selected, taken in conjunction with the characteristics of the deposit, brought about a reduction to half this variance, the standard deviation would be 0.21 pct and the expected amount of ore would fall to about 32 pct. If the reduced variance is one third the original variance, standard deviation would be 0.17 pct and the expected amount of ore would decrease to 28 pct. Although fairly subtle, these changes may cause large deviations between estimates and results if they are not taken into consideration.

Use of Analytic Frequency Functions: It often happens, in predictions of quality distribution, that there are not enough samples to form an acceptable frequency distribution. When this problem arises it is possible to use any one of the various analytic frequency functions having self-reproductive properties and adequately describing the distribution of quality in the deposit. The electronic computer may be used in this case also, but a synthetic frequency function is believed more reliable. Such functions, in a sense, embody the results of the geological influences that shaped the distribution of quality and for this reason may be expected to smooth out the random fluctuations, inevitable in a small group of samples, in a manner concordant with the factors that produced the deposit.

Of these functions, two are appropriate to the distribution of quality in the magnesite deposit at Gabbs, namely, the negative binomial distribution and the logarithmic normal distribution. The first of these will be illustrated here.

The frequency distributions from the Gabbs deposit are highly skewed positively and so are not adequately described by the normal distribution, which was used in the foregoing discussion only for the sake of simplicity. The equation of the negative binomial distribution is:

$$f(x) = \left(\frac{m}{1+Bm}\right)^{x} \frac{(1+B)\,(1+2B)\ldots[1+(x\text{-}1)B]f(0)}{x!} \qquad [7]$$

Details concerning this distribution may be found in Burrington and May,[32] Feller,[33] and Condon and Odishaw.[34] A recursion formula more useful for computing such a distribution over its whole range is given below along with the significance of the various symbols.

$$f(x) = f(n+1) = f(n)R\left[\frac{Bn+1}{n+1}\right] \qquad [8]$$

$$R = \left(\frac{m^2}{s^2}\right) \qquad [8a]$$

$$B = \frac{s^2-m}{m^2} \qquad [8b]$$

Table III. Negative Binomial Frequency Distributions

Grade Interval	Range, Percent CaO	Mined Ore Obs.	Mined Ore Calc.	Designed Pit Obs.	Designed Pit Calc.	Derived n = 3.1	X^2 Interval
0	0 to 2	267	247	360	317	109	0
1	2 to 4	218	186	178	185	198	1
2	4 to 6	129	140	103	127	213	2
3	6 to 8	71	105	80	91	178	3
4	8 to 10	31	79	46	67	126	4
5	10 to 12	78	60	54	50	80	4
6	12 to 14	39	45	37	39	47	5
7	14 to 16	41	34	27	29	26	5
8	16 to 18	42	25	21	22	14	6
9	18 to 20	9	19	17	17	7	6
10	20 to 22	23	14	6	13	3	7
11	22 to 24	18	11	21	10	—	7
12	24 to 26	13	8	17	8	—	8
13	26 to 28	10	6	16	6	—	8
14	28 to 30	7	5	11	5	—	8
15	30 to 32	7	4	6	4	—	8
	Chi-squared	—	12.38	—	8.04	—	
	$P(m = 6)$	—	0.11	—	0.24	—	
	Mean	—	3.05	—	2.75	2.75	
	Variance	—	12.32	—	12.96	3.99	
	B	—	1.00	—	1.35	0.16	
	$f(0)$	—	0.25	—	0.32	0.10	
	R	—	0.753	—	1.35	1.90	

$$f(O) = \left[\frac{s^2}{m}\right]^{\frac{-1}{s}} \qquad [8c]$$

Table III shows the calculated negative binomial distributions corresponding to the mined ore and the ore in the designed pit. The results of the chi-squared tests[15] show only moderately good fits. However, from a practical point of view, inspection of the table shows that the variations for the various grade intervals are, for the most part, not alarming in view of other uncertainties afflicting the case.

The negative binomial distribution for the mined ore was adjusted by reducing the variance and calculating several derived distributions so that a curve could be drawn relating n (multiplicity) with the amount of ore containing 2 pct lime. Fractional values were freely used for n, a recourse not readily available when distributions are derived on the computer. The estimated value for n turned out to be 3.1, in quite satisfactory agreement with the values of 3.1 and 3.2 found previously. The derived distribution for the ore in the designed pit is also shown in Table III for this value of n. The relative frequencies shown for the various grade intervals are in reasonable agreement with the computer results, which may be read from Figs. 7, 8, and 9, at the value 3.2 for n.

Table IV. Percent CaO in Core Analysis

2.62	11.48	15.68	1.98
0.66	1.12	0.77	3.45
15.80	11.91	0.77	2.36
1.81	3.20	3.51	0.60
2.59	1.99	11.58	10.48
0.89	1.03	1.52	

Now that the type of distribution to be used has been decided upon, and the value for n deduced, an illustration of an application to a single bench may be given. Table IV shows the analyses of 23 cores from the core drillholes passing through one of the benches in the pit. One of the problems encountered in planning production from this pit is that of predicting the rate at which ore of various grades will be produced in the future. To judge from the analyses in the table, well over half the ore on this bench should be of excellent quality, while there should be only a little ore lying in the intermediate range which is used for flotation feed.

These holes are roughly at random locations on the bench. They represent about 220,000 tons of ore. Taking moments in terms of the arbitrary grade intervals, $m = 1.84$, i.e., the average lime concentration is 4.68 pct. The variance is 6.306 in the arbitrary units, but this value must be adjusted for bias on account of the smallness of the sample (16) using the factor $(n\text{-}1/n)$ or 23/22 where n is the number of samples. The adjusted value is 6.593. When this is divided by 3.1, the multiplicity determined for the deposit gives the reduced variance 2.13. This value and Eqs. 7 and 8 are used to calculate Table V.

Table V. Expected Quality Distribution Single Bench

X	CaO, Pct	$f(x)$	X	CaO, Pct	$f(x)$
0	1.0	0.179	4	9.0	0.065
1	3.0	0.285	5	11.0	0.026
2	5.0	0.246	6	13.0	0.009
3	7.0	0.153	7	15.0	0.003

The amount of high-grade ore averaging 2 pct lime as estimated from this distribution is 35.8 pct. The amount estimated from the quality contour map prepared from the analysis of the blast drillholes was 42 pct. About 30 pct of the bench was actually recovered as ore of this grade. The amount of ore of a grade suitable for flotation feed at an average lime concentration of 4.5 pct is estimated from Table V to be 35.1 pct. The amount shown on the contour map was 38.2 pct. No record was kept of the amount of this quality actually mined from the bench in question, but it seems reasonable that the agreement between prediction and performance would have been acceptable. Certainly both the proportions calculated here are far more accurate than the expectation based on the unadjusted core drill analyses.

Conclusion: In presenting the results reported in these paragraphs, the writer has been constantly tempted to discuss each of the many side issues that have been raised either overtly or by implication. No doubt his attempt to steer a middle course will leave some readers with the impression that grievous omissions have been incurred and others with the impression that trivial facts have been belabored. All questions dealing with statistical theory have been left for investigation by those sufficiently interested to turn to the standard texts covering this subject. The author has not attempted to write a text on statistics and probability and does not claim the competence needed for such a task. The reference given will provide an excellent starting point for a fuller inquiry into the theories presented here.

The author does strongly believe that adjustments such as those proposed here and used with some success on the deposit in question have more theoretical justification than the blind practice of assigning uniform quality to large, sometimes vast blocks of ore and then expecting these blocks to distribute themselves quality-wise in accordance with the small number of samples that have been analyzed. When hand sorting is used this practice is justifiable, but with large-scale modern mining methods, some reduction in the spread of quality is inevitable and measures should be taken, using all the statistical tools available, to determine the amount of this reduction and the nature of the resulting distribution.

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[15] R. S. Burrington and D. C. May: *Handbook of Probability and Statistics*, p. 178 et seq.
[16] H. Cramer: *Mathematical Methods of Statistics*, p. 351.

Discussion of this article sent (2 copies) to AIME before Nov. 30, 1959, will be published in MINING ENGINEERING.

TECHNICAL NOTE

FISHING TOOLS FOR RETRIEVING GAMMA-RAY LOGGING COMPONENTS

by CARL M. BUNKER and J. M. OHM

Two special tools for recovering gamma-ray probes and logging cable from drillholes have been designed by Ohm and Bunker and constructed by Ohm. Though intended specifically for U. S. Geological Survey equipment, they may be used with other equipment of the same general type.

Fishing Tool for Probes: A fishing tool of the overshot type (Fig. 1) was designed to retrieve logging probes (sondes) that become disconnected from the logging cable and are trapped in the drillhole. When the tool slides over the top of the gamma-ray probe, studs on the bottom engage the shoulder near the top of the probe (Fig. 2), which is then pulled to surface.

The barrel can be constructed from brass or steel tubing. Wall thickness is not a critical dimension, but the tool should be heavy enough to sink through mud or water in the drillhole.

The internal length of the tool must be enough to prevent interference with the upper end of the probe head as the tool slides over it. The design of the probe head used by the USGS required a minimum free space of 2½ in. inside the fishing tool, which was made 7½ in. long to increase the weight.

The lower end, which engages the shoulder of the upper end of the probe, contains three studs placed at 120° around the circumference of the tool and held in the engaging position by the tension of a spring wire. The studs can be made of any metal, such as steel, having high tensile strength. As the tool slides over the probe the studs are pushed outward from the center against the spring tension, allowing the tool to slide into position below the shoulder of the probe head. The spring tension forces the studs inward into the engaged position after they pass the shoulder. When the tool is raised the studs stop against the shoulder, preventing the tool from sliding up over the top of the probe. Once it engages the shoulder of the probe it cannot be freed until both probe and fishing equipment are recovered from the drillhole.

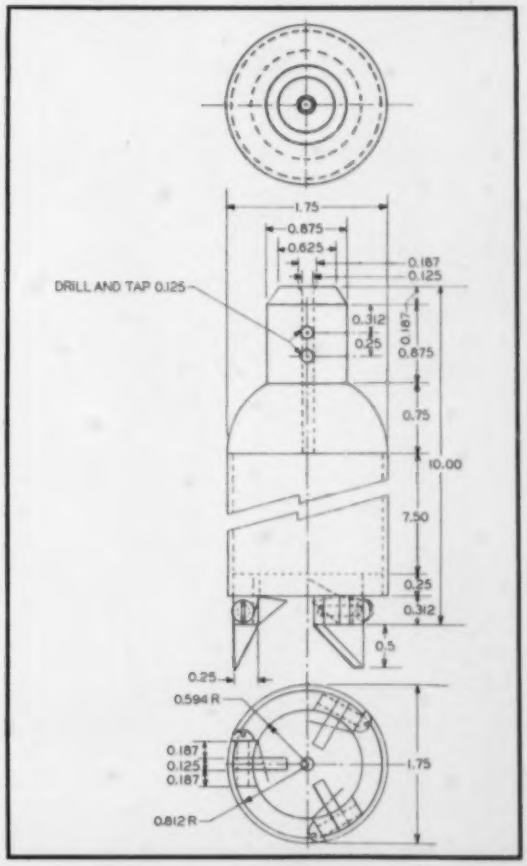

Fig. 1—Fishing tool for retrieving probes.

C. M. BUNKER and J. M. OHM are with the Geophysics Branch of the U. S. Geological Survey, Denver. TN 59 I 211. Manuscript, Feb. 16, 1959. AIME Trans., Vol. 214, 1959.

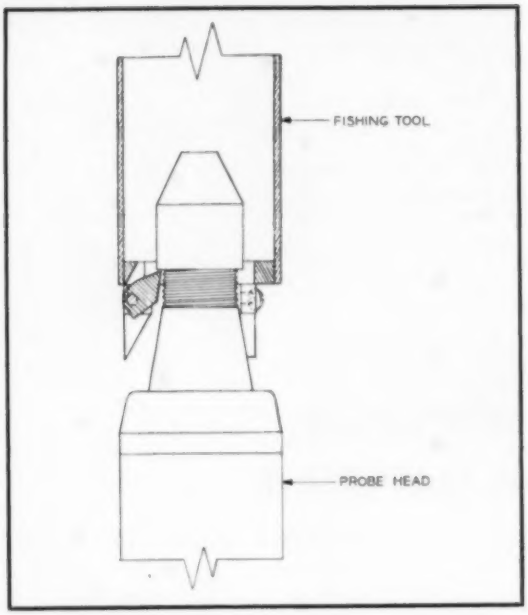

Fig. 2—Tool with probe in retrieving position.

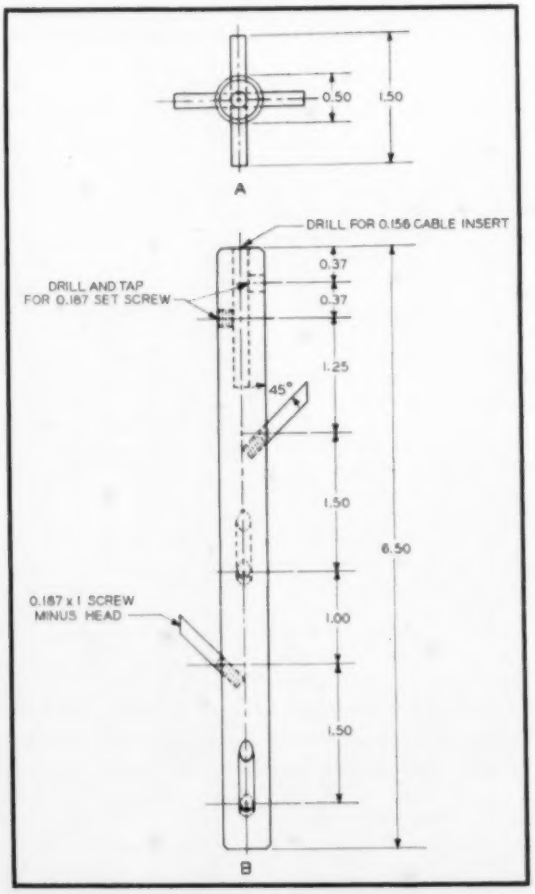

Fig. 3—Fishing tool for retrieving cable.

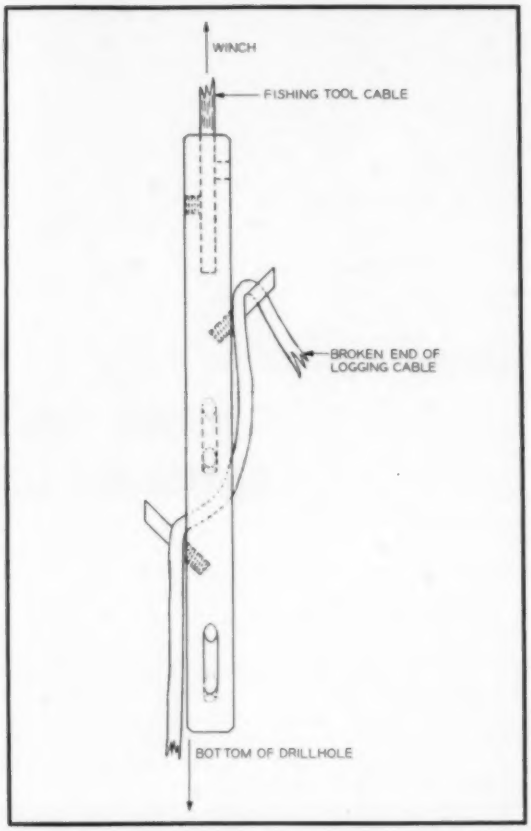

Fig. 4—Tool with cable in retrieving position.

The fishing tool is attached to a steel cable and lowered by hand into the drillhole. After the location of the probe has been determined, the tool is raised a few inches and then lowered rapidly to force it over the head of the probe. In a large drillhole it may be necessary to do this several times before the tool can be centered over the probe, but when the drillhole diameter is only slightly larger than the probe and fishing equipment, the tool is easily guided. Once the tool and probe are engaged, the upper end of the fishing cable can be attached to a winch or block and tackle and the equipment can be retrieved from the drillhole.

Fishing Tool for Cable: The tool designed for recovering broken logging cable from drillholes is simple but effective. A steel rod 7 to 8 in. long is drilled with four holes placed at 90° around the circumference (Fig. 3A), about 1½ in. apart vertically and pointing downward at a 45° angle from the center line of the rod (Fig. 3B). The holes are tapped and 5/32-in. screws 1 in. long are screwed into them. The heads of the screws are cut off at an angle parallel to the body of the tool. A hole is drilled in the center of the upper end of the tool to accept the winch cable. Two more are drilled into the side of the rods to intercept the hole drilled for the cable and are tapped for set screws.

The tool is lowered as far as possible into the drillhole containing the logging cable by a winch cable of high tensile strength. It is then raised and lowered repeatedly until the logging cable is entangled in the studs projecting from the tool (Fig.4).

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• IndMD page 1051
• MBD'ers Digest page 1053

AIME's 13 LEADING LOCAL SECTIONS IN MEMBER GIFTS CAMPAIGN FOR NEW UNITED ENGINEERING CENTER

Data correct as of Oct. 1, 1959. Note: Oregon is only AIME Section that ranks among the first 13 on all 5 counts. For story and picture, turn back a page.

Total Amount Pledged:

1)	New York	$107,883
2)	Gulf Coast	27,226
3)	New York Petroleum	12,671
4)	Utah	10,105
5)	San Francisco	9,600
6)	Arizona	6,889
7)	Ohio Valley	6,606
8)	Pittsburgh	6,241
9)	Dallas	5,972
10)	Oregon	5,842
11)	Penn.-Anthracite	5,665
12)	Mid-Continent	5,520
13)	St. Louis	4,674

Average Pledge per Section Member:

1)	New York	$69
2)	New York Petroleum	47
3)	Oregon	40
4)	Uranium	36
5)	Hugoton	24
6)	Penn.-Anthracite	20
7)	Gulf Coast	19
8)	Ohio Valley	16
9)	Montana	16
10)	Tri-State	15
11)	Utah	14
12)	Lehigh Valley	13
13)	East Texas	12

Percent of Membership Pledged:

1)	Hugoton	78%
2)	Carlsbad Potash	69
3)	Gulf Coast	59
4)	Upper Mississippi Valley	52
5)	Oregon	42
6)	Uranium	41
7)	Tri-State	41
8)	Penn.-Anthracite	40
9)	East Texas	39
10)	Lou-Ark	38
11)	Billings Petroleum	37
12)	South Plains	35
13)	Black Hills	35

Percent of Goal Reached:

1)	Oregon	343%
2)	New York Petroleum	311
3)	Uranium	235
4)	Penn.-Anthracite	172
5)	Hugoton	163
6)	Ohio Valley	138
7)	Montana	136
8)	Tri-State	130
9)	Gulf Coast	124
10)	Utah	124
11)	Lehigh Valley	114
12)	Carlsbad Potash	102
13)	San Francisco	100

Average Amount of Pledges:

1)	New York	$329
2)	New York Petroleum	218
3)	North Texas	187
4)	Central New Mexico	108
5)	Oregon	97
6)	St. Louis	90
7)	Uranium	88
8)	Nevada	87
9)	Cleveland	85
10)	Kansas	81
11)	Florida	75
12)	Arizona	73
13)	San Francisco	71

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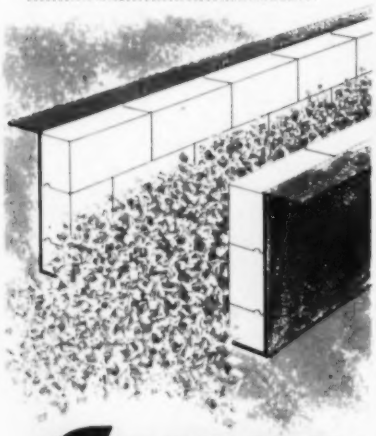

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FERRO CORPORATION
East Liverpool, Ohio

Explosives Set Theme Of Mining Research Meet

The University of Missouri School of Mines and Metallurgy and the U. S. Bureau of Mines will collaborate again this year for the Fifth Annual Symposium on Mining Research, November 19 to 21, in Rolla, Mo.

Ammonium nitrate explosives will be the main subject of discussion in response to intense interest in theory and application of these explosives. There will also be six papers on field usage and results.

Other tentative topics include safeguarding explosives and blasting agents, safe practices in use of blasting agents, secondary blasting with AN explosives, effect of particle size on explosive properties, results of AN explosive research at Missouri School of Mines, and physical and chemical characteristics of fertilizer grade ammonium nitrate.

Space Age Metals Will Be 1960 Meeting Theme

The Southwest Metals and Minerals Conference will be held on April 21 and 22, 1960, at the Ambassador Hotel in Los Angeles. Henry T. Mudd, president of Cyprus Mines Corp., is general chairman of the conference committee. The San Francisco and Reno Sections joined the Southern California Section as sponsors.

Metals and materials for the space age is the theme of the conference. Metals such as boron beryllium, lithium, thorium, and rare earths will be discussed. Further details will be reported as plans for the spring meeting are unfolded.

C. R. Kuzell Will Give 1960 Metallurgy Lecture

The Metallurgical Society of AIME has announced that Charles R. Kuzell will deliver the 1960 Extractive Metallurgy Lecture at the AIME Annual Meeting in New York, Feb. 14 to 18, 1960.

Mr. Kuzell, director of the Phelps Dodge Corp. and former AIME Director, received the 1956 AIME James Douglas Gold Medal for outstanding contributions to nonferrous metallurgy. His theme for the lecture will be the development of modern copper smelting.

Lake Superior Safety Council Convened

A meeting of interest to mining men was held in Duluth, May 21 and 22, sponsored by the Lake Superior Mines Safety Council. It was the 35th annual meeting of the Council, with 650 attending, representing 20,000 mine workers in Minnesota, Wisconsin, and Michigan.

H. D. Scott, Council president, gave the opening address. Interesting papers presented included *Open-Pit Plant Safety* by W. F. McDermott of Pickands Mather & Co.; *Handling Materials Safely* by Walter G. Kuta, U. S. Steel Corp.; *Long Hole Raising* by Richard C. Annear of Inland Steel Co.; and *Our Unsafe Mines* by John D. Grimaldi, General Electric Co.

Special exhibits and banquet rounded out the program, with Robert D. Forte as banquet speaker. Mr. Forte is the supervisor of sports relations and promotion for Miller Brewing Co., Milwaukee.

AIME

BOARD OF DIRECTORS

Recent actions taken by the Institute Board of Directors.

► The Metallurgical Society has announced that the recipient of the 1959 McKune Award was G. M. Hagenberger, Standard Steel Works Div., Baldwin-Lima-Hamilton Corp., Burham, Pa., for his paper *Conversion to 70 pct Natural Gas Utilizing a Continuous Oxygen and Combustibles.*

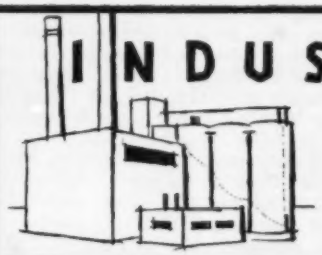
► Ernest O. Kirkendall was appointed AIME representative at the board meeting of the National Soc. of Professional Engineers, held at the Hotel Commodore, New York, June 17 to 20.

► Terms of AIME representatives on EJC committees have been extended to Aug. 31, 1960, instead of Dec. 31, 1959.

Utah Section Student Papers Receive Awards

The judges for the Utah Section have announced the winners for this year's Student Prize Paper competition. In the graduate division the best paper was *Infrared Analysis of Inorganic Solids Encountered in Smelter Processes* by Robert Lee Martin, Jr. In the undergraduate division first prize was awarded to Leo A. Rogers for his paper entitled *Spectrophotometric Analysis of Niobium.* Second prize went to Gordon R. Dorny for his treatise on *Sulphidizing of Partially Reduced Oxides of Copper.*

As in previous years, a number of excellent papers were submitted by the Utah students. Cash awards were presented at the September meeting of the Utah Section, and the three papers will be submitted to the AIME National Student Prize Paper contest.



INDUSTRIAL MINERALS NEWSLETTER

Dear Members of IndMD:

We had a letter recently from Richard Brooks that was a corker. Dick, you may recall, is serving as Pacific Southwest vice chairman for the Industrial Minerals Division. He was replying to an inquiry from us relative to AIME's Salt Lake City office. This particular item was a holdover from previous Executive Committee meetings and we were trying to organize the agenda for our Bedford Springs get-together by pre-polling the group on it. Because he raised some questions which we believe are fundamental to the Division and SME we would like to quote the meat of it here for you.

> You are questioning us in terms of the benefits the Industrial Minerals Division receives in return for participating in defraying the cost of the (Salt Lake City) office.
>
> But tell me, what role does Industrial Minerals Division want to play in the West? I seem to have a feeling that the Division is strictly an eastern activity of SME. Do you think it makes any active contribution to our professional activities and interests in the West? It seems to me that whatever is done out here is done without any reference whatsoever to the Division.
>
> Could one ask the question, why should members of SME in the West accede to having a portion of their dues spent to support the activities of the IndMD Division? It is somewhat like asking us to support the Southern Appalachian Section, or whatever. How many western IndMD members will be able to participate in the Bedford Springs meeting—or participated in recent (eastern) meetings?

First and foremost, Dick, it's safe to state categorically that as part of SME the Industrial Minerals Division is most certainly not intended to be an eastern activity of the Institute. A quick glance at the organizational structure of the Division with its geographical vice chairmen will answer that. But maybe we are a provincial lot and maybe we have failed to do missionary work in the West, despite the attempt on paper to cover the whole country and Canada.

(Editorial Note: *IndMD Secretary Ray Feierabend is much too modest about the role played by the Division in the West. Not only have individual members of the Division been active participants in regional and local meetings, but the Division's regional vice chairmen were among the organizers of the important Pacific Northwest, Rocky Mountain, and Pacific Southwest regional conferences. As a matter of interest, Vernon Scheid's name crops up among those who put together the very first Pacific Northwest Industrial Minerals Conference. He later served as the chairman of the first Pacific Southwest Conference. W. F. Rappold was listed as one of the six responsible for the first Rocky Mountain Minerals Conference. Both were IndMD regional vice chairmen when they helped organize these meetings. The Division has assisted other meetings informally through the work of its program committee.*)

It is a many-faceted problem and what the underlying causes are, we are not certain. But it is a challenge for the whole Division. If we can find the answers we should be able to increase our effectiveness and multiply the services to our members.

We would venture to bet that some of the metals producers in the east feel about the Mining and Exploration Division as possibly the westerners feel about Industrial Minerals. We tend to identify geographical sections of the country AIME-wise with their major minerals commodities: the Arizona Section and copper, the Pittsburgh Section and coal, the South Texas Section and oil. Likewise most of us have come to think of Salt Lake City as headquarters of the Mining and Exploration Division because it is a mecca for non-ferrous metal mining plus the fact that Salt Lake has an abundance of active AIME members. On the other hand, we doubt seriously that there is any Local Section that can be called purely an Industrial Minerals local section. So far as we know there is no geographical division of the U. S. that is the Industrial Minerals province. True the Gulf Coast is the sulphur center, Carlsbad the potash center, Florida the phosphates, but each is only one of the many minerals relegated to our Division. We cover so many minerals and their uses that sometimes it is quite difficult to find any relationship between or among the committees which represent them.

We literally run the gamut—from the pigment in the paint on the crib to the polished marble or granite tombstone on the grave. We suffer from "excessive heterogeneity" which for some reason works against us but which actually should be in our favor.

Seems to us that our aim within the Division is to be equally effective all over the country wherever nonmetallic minerals are produced and used. We are at a loss to know, Dick, why the Division is not making some active contribution in professional circles in the West. Could it be that non-metallics are produced over such a widespread area of the country that we are, in effect, so highly outnumbered on the local level that we lose our collective effectiveness? It is mighty easy to get that "fish out of water" feeling and without a little effort just drop out of AIME work. If I may use myself as an example: I pledge allegiance to SME as an Industrial Mineralist (Chem. Raw Mat'ls) with a secondary interest in Mining and Exploration. But I live right in the middle of the oil patch and our 500-strong local section is an SPE Affiliate. It is awkward, admittedly, but all in all it works out pretty well for the handful of us outsiders who join in. We had to join in for we could not beat them. True, a high powered talk on reservoir mechanics doesn't "send us" but we do have a chance to rub elbows with fellow AIME'ers—and who knows what friendly professional associations lead to? We even present papers occasionally. I know first hand how easy it is to be submerged in the crowd, but you simply have to accept the facts and make the most of it.

Then, too, we wonder if conflict of interest enters into the problem. We in IndMD tackle the geology, exploration, mining, preparation, and marketing of the non-metallics. But

(*Continued on page 1052*)

EDITOR

Address news items to:

R. H. Feierabend, IndMD Secretary-Treasurer, Freeport Sulphur Co., P. O. Box 1520, New Orleans 5, La.

IndMD News

(Continued from page 1051)

despite the specific commodity interests isn't it just plain logic, for example, that the underground potash miner or open pit uranium producer should feel closer kin to the mining crowd? Geographically he's nearer and his operating problems, by and large, have their counterparts in metal mining. Mining after all is mining irrespective of the materials produced, broadly speaking. Is it not natural that such a one will seek his outlet and contacts where he can make the greatest contribution and have the best chance to help himself? Maybe in this we can work a bit closer with our sister Divisions to the benefit of all.

The strength and usefulness of any organization such as ours is, we believe, measured by the degree to which the membership takes part in its activities. In AIME the focal point is the Annual Meeting, and to a lesser extent on the regional or society meetings. Each year's committees concentrate on the organization and assembling of the technical and social sessions for the convention. If, through subject matter, location, or some other reason we fail to create a desire in our members to attend, then we have missed the boat, and we should find out what's wrong. If, as we infer from Dick Brook's comment, locating the meetings in the East—Bedford Springs, Tampa, Nova Scotia, St. Louis—kills the interest and incentive for the folks out West to join in, then something ought to be done about it.

Number-wise the Industrial Minerals Division is the smallest in SME. As for the value, diversity, and tonnage of minerals produced, we represent the largest. A large membership just for numbers sake is not in our thinking. We don't want to be the largest— only the best, and the best measured by the service to our members through active participation. We believe this Newsletter can make a worthwhile contribution to our Division affairs. But it can't be done without your help, advice, and encouragement. Let us hear from you, please!—*Ray Feierabend.*

Photo - Courtesy, United States Steel Corporation.

Tough cars for a big job . . .

In 65 years or so the first dipper hole at Mesabi has grown to the tremendous open pit pictured here in part. Differential Air Dump Cars first put in appearance at Mesabi in 1925. Veterans of many years and thousands of tons, these cars have carried their loads uncomplainingly. Steady reorders have a pleasant way of nodding approval. We would be glad to tell you more about Differentials — how they're made and why you'll like them.

PIONEERS IN HAULAGE EQUIPMENT SINCE 1915

DIFFERENTIAL STEEL CAR COMPANY
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Pittsburgh Will Hold An Off-the-Record Meet

On November 6 the Pittsburgh Section will combine with the Engineers' Society of Western Pennsylvania for their 14th annual Off-The-Record Meeting. Headquarters will be the Penn-Sheraton Hotel in Pittsburgh. Other contributing groups are SME's Coal Division; NOHC; and the Section's Petroleum Subsection, Institute of Metals Group, and Mineral Industry Group.

All five groups will hold simultaneous sessions in the morning and afternoon, joining for lunch and a fellowship dinner in the Ballroom, and a cocktail party in the Urban Room.

R. M. Barnhart will be toastmaster for the dinner at which the F. L. Toy Award will be presented. Speaker for the evening is Clifford C. Furnas, chancellor of the University of Buffalo. Dr. Furnas has been active in research work for Illinois Steel Co., the U.S. Bureau of Mines, Curtiss-Wright, and Cornell Aeronautical Laboratory, where he was made executive vice president in 1948. He has also served as assistant secretary of defense for research and development in Washington.

The Pittsburgh Section will meet in the Fort Duquesne Room under the co-chairmanship of Oscar M. Wicken and Otto W. Werner during the morning, and Joseph G. Sevick and Warren M. Mahan in the afternoon. Films on zinc, bauxite mining, and copper refining will be interspersed with the papers. Some of the topics to covered include airborne magnetometer surveys, coal pipeline development, and zinc sinter, physical testing studies. The speakers for the morning session are G. M. Heinitsh, Tom Reagan, R. J. Lund, and W. S. Agocs. In the afternoon D. E. Warnes, E. J. Wasp, and S. A. Gustavson will speak. J. H. Henderson is chairman of the Pittsburgh Section.

ROCK IN THE BOX

Mining & Exploration Division

Louis B. Slichter Will Receive The Jackling Award

L. B. SLICHTER

The Daniel C. Jackling Award for 1959 will be given to Louis Byrne Slichter at the 1960 Annual Meeting in New York. The award and accompanying lecture have become a major feature of the Institute meeting each year, in honor of the renowned mining pioneer and executive who was President of AIME in 1938. In 1953 the award was initiated by the Mining, Geology, and Geophysics Division. A bronze plaque will be presented for "significant contributions to technical progress in the fields of mining, geology, and geophysics."

Dr. Slichter is director of the Institute of Geophysics at the University of California in Los Angeles. He has held this post since 1947, and has had a long career in education and research, beginning with his undergraduate study at the University of Wisconsin. He received his B.A. there in 1917 and went on to earn a Ph.D. in physics in 1922. For the following two years he was an ensign in the U.S.N.R. and then physicist for the Submarine Signal Corp.

For seven years he was partner in the firm Mason, Slichter & Gauld before going to the California Institute of Technology as research associate. This led to his appointment as associate professor of geophysics at Massachusetts Institute of Technology where he became full professor a year later and remained for 13 years.

In 1945 he accepted a professorship at the University of Wisconsin, his alma mater, and was a Rockefeller Research Fellow in 1946 before attaining his present position.

EDITOR

Address news items to:

John W. Chandler, American Metal Climax Inc., 61 Broadway, New York 6, N. Y.

His other awards include a citation "in recognition of eminent professional services" when he left the University of Wisconsin, and a Presidential Certificate of Merit. He is also a member of the National Academy of Sciences.

His list of published papers extends from 1929, when he wrote the AIME Transactions paper *Certain Aspects of Magnetic Surveying*, to 1959 when he has had published three papers entitled 1) *Field of an Alternating Magnetic Dipole on the Surface of a Layered Earth;* 2) *Mining Geophysics;* and 3) *Some Aspects, Mainly Geophysical, of Mineral Exploration.* In addition to the many published papers, he has been granted several U. S. patents, including an early patent on the electrical logging of drill holes, conceived in 1927 and assigned to the Schlumberger Well Surveying Co.

Education News

University of Arizona

The University of Arizona scientists believe that commonly accepted explanations of relationships between geology and the occurrence of groundwater may have to be altered. The University's study of the utilization of arid lands has produced a new view which may change the whole concept of groundwater recharge in Arizona and other arid lands. The three-year research program in which five major fields of science are represented is supported by the University, The Rockefeller Foundation, and the groundwater branch of the U. S. Geological Survey. A. R. Kassander, Jr., chairman of the committee, revealed the new geology-groundwater relationship development. The members of the program are highly pleased with initial results.

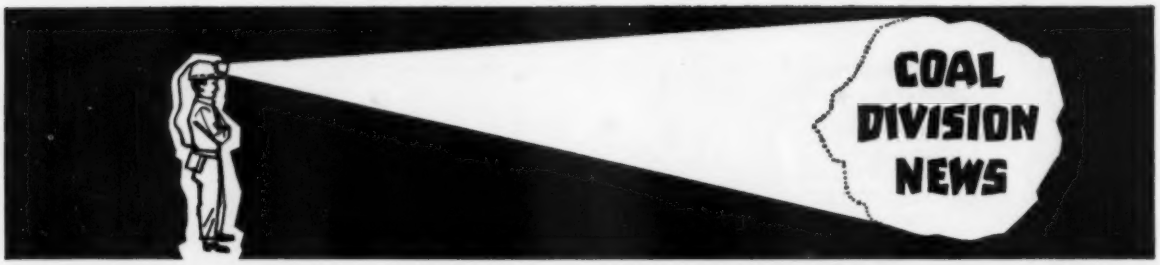
• J. B. Cunningham has retired as head of the Dept. of Mining & Metallurgical Engineering at the College of Mines, University of Arizona. He will continue to serve as professor. Thomas M. Morris is the new head of the department, effective in September. Professor Morris has taught for a number of years at the Missouri School of Mines and Metallurgy. In another departmental change, the chemical engineering curriculum will be given separate status next year, no longer within the Mining and Metallurgical Dept. The new department will be headed by Donald H. White.

Colorado School of Mines

An unrestricted gift of $10,000 has been donated by the American Metal Climax Foundation to the Colorado School of Mines and will be used for faculty improvement. American Metal and Climax individually had been consistent supporters of the mineral engineering program at the school, and this is their first gift together since their merger in 1957.

Virginia Polytechnic Inst.

The Department of Geological Sciences of Virginia Polytechnic Inst. has been awarded approximately $9000 by the National Science Foundation for an undergraduate research program in geology and geophysics. Ten selected seniors have received $450 plus subsistence, lodging, and travel while in the field. They were enrolled in the Summer Field Geology Course at Saltville, Va., from June 15 to July 25, conducting field research projects under supervision. They will continue their research on the campus in the fall and winter, offering papers covering their findings.



Rocky Mountain Meet Debates Coal's Future

The 55th annual meeting of the Rocky Mountain Coal Mining Institute was held at the Antlers Hotel, Colorado Springs, from June 29 to July 1. R. R. Williams, Jr., manager of mines for Colorado Fuel and Iron Corp. in Pueblo, Colo., is president of the organization. Mr. Williams opened the meeting by commending the management of the coal industry for their increasing efficiency in mining that has permitted a stable price for coal.

A business session began the three-day conference with the election of officers for the coming year. W. K. Dennison, manager of Raton operations, Kaiser Steel Corp., became the new president. Vice presidents elected are Victor Forstrom, A. Z. Dimitroff, C. M. McConnell, C. C. Cornelius, and G. E. Sorensen.

Fred W. Whiteside, consulting engineer, will be secretary-treasurer, and the executive board is as follows: W. M. Kerr, M. C. Heffelman, Tony Fratto, Edward Prostel, and C. W. Johnson.

Honorary life memberships were also awarded at the business session to the following retired members: J. R. Kastler, Fred Koelling, J. B. Morrow, Gomer Reese, and G. H. Smith.

After the business session, keynote remarks were given by Elmer F. Bennett, Under Secretary, U. S. Dept. of the Interior. He expressed the need for the coal industry to keep abreast of developments in the western states, citing increased population and advanced technology as reasons for his stand. Coal production is substantially lower than it was two decades ago, but new developments and reopened mines show that a brighter future is possible for coal if added effort is made now at the laboratory level.

R. T. Person discussed *Fuel for Tomorrow's Power*, pointing out that utilities now consume 100 pct more coal than they did in 1947, replacing the loss of the railroad fuel market. By 1965 there should be a 50 pct increase in residential power consumption. Competition from nuclear power, not a threat before 1965, and oil-shale gas necessitate increased efficiency and better cooperation between coal and power companies for the highest possible utilization of coal.

Recent Trends in Coal Strip Mining was the topic covered by L. M. Cooley, manager of Edna Coal Co. in Denver. He mentioned the ingenuity of equipment manufacturers and of management in reducing the cost of mining through use of better tools and methods.

A. Lee Barrett, director of research and development at Joy Manufacturing Co., presented a paper on *Face Dust Collectors* and J. H. McKenzie, assistant safety director for Socony Mobil Oil Co., gave an *Evaluation of a National Safety Problem—Off-the-Job Accidents*. His main points, after stating that accidents off-the-job are even more time and labor consuming than industrial accidents, were that people should organize for safety, inspect environmental hazards, and learn the proper steps in case an accident does occur.

Functions and Policies of the Industrial Commission of the State of Utah was the presentation of Otto A. Wiesley, chairman of the commission. He declared that since its inception in 1917 the commission has increased in effectiveness through cooperation with labor, management, and the medical and legal professions.

Tony Fratto, maintenance superintendent for Independent Coal & Coke Co., discussed *Power Distribution and Power Cables for AC Shuttle Cars*. He described the Castle Gate installation, showing a substantial reduction in costs of supplies and labor for cable maintenance over previous systems.

Two films were included in the program, presented by Warren Gerler of Link-Belt Co. and R. E. Cope of Texaco Inc. The first film showed the operations of the Moss No. 3 plant of Clinchfield Coal Corp., and the second film covered the characteristics, testing, and compounding of hydraulic fluids for industrial applications.

Final speakers covering coal mining topics were J. W. Woomer, consultant; Earl R. Maize, USBM safety engineer; and Leif Arentz, Lee-Norse Co.

Their papers presented at the conference included *Responsibilities of Management and Engineers in Helping the Coal Industry Get New Money to Perpetuate Itself*, *Coal Mining in Australia*, and *Bending Coal Mine Roof*.

1960 Strata Control Conference Scheduled

An International Conference on Strata Control is being planned by the French Coal Industry for May 16 to 20, 1960, in Paris. AIME members are cordially invited to attend. The conference will be held at the Centre Marcellin-Berthelot (Maison de la Chimie) 28, rue Saint-Dominique. It is being organized by the Centre d'Etudes et Recherches des Charbonages de France.

Official conference languages will be French, English, and German. The papers will be translated and distributed to all delegates in advance so that the working sessions will be devoted exclusively to discussion of the papers. An international committee has been selected from Germany, Belgium, Great Britain, France, and The Netherlands, to choose the papers and make final arrangements.

Since the field of strata control is very wide, the conference is restricted to a limited number of problems, to ensure that these questions are examined thoroughly. The investigation of pressure and its effects in underground winning workings and the roads serving these workings, particularly the recent results obtained from laboratory experiments, underground measurements and observations will constitute a major portion of the conference. Problems relating to work in shafts and in main roads, or dealing with methane, or instantaneous outbursts are excluded from the conference, as is the study of surface movements.

Papers discussing support equipment may only be presented by practical mining experts, and must describe practical applications of the equipment. Papers on supports by manufacturers will not be accepted.

The last working session of the conference will be reserved for the presentation of the national reports which will provide, country by country, a general statistical survey of developments and trends in roof control technique.

An open invitation to submit papers for the conference is extended by the committee to all AIME members.

Around the Sections

Okley B. Bucklen (right) received the Old Timers Club award at the Annual Buckhart Mining Society Dinner from his brother, Ellis Bucklen, who won the award in 1954.

• **Southwestern New Mexico Section** held its annual meeting in the Bayard Lions Club on Jan. 30, 1959. Vice Chairman Snell presided. The following nominations for 1959 officers were approved: Clarence C. Snell, chairman; Robert W. Shilling, first vice chairman; John M. Sudler, second vice chairman; and David W. Boise, secretary-treasurer. After the business reports Barney L. Himes spoke on *Human Relations in Industry* and Howard A. Wilmeth gave a paper on Chino's proposed skip hoist. At a later date Chairman Snell appointed Charles L. Lockart chairman of the membership committee and Rupert B. Spivey chairman of the program committee.

• Highlights of the May meeting of the **Adirondack Section** were the mine and mill trips through Republic Steel Corp.'s operation at Mineville, N. Y. After the dinner, financial matters were discussed and Student Affairs prizes were awarded for the best essays as judged by Gene Eastman, Mike Reilly, and Bob Heinrich. First prize went to Judy Shattuck, second prize to Frances Michalik, third to Paul F. LeBlanc. Those who received honorable mention were: Martha Evans, Nola Joy Risley, and Maisha Latham.

• The **Colorado Plateau Section** spring meeting featured technical papers, tours, family fun, dinner, and dancing, with headquarters at the Beaumont Hotel, Ouray, Colo. on June 20. After a morning of swimming, a business meeting convened and the following papers were presented: *Coal, Coal Photography in Connection with the Nevada Power Project*, by F. L. Smith; *Standard Uranium's Program for 1959 for the San Juan Mountains*, by R. Wood; and *The Development of the Oil and Gas Fields in the Paradox Basin*. A new chairman was elected to finish the term of J. W. Halser who has moved to Denver. Gilman C. Ritter became chairman while Mark Shipman remained second vice chairman, and T. S. Ary secretary-treasurer.

AIME Student Chapters

The following AIME Student Chapters were omitted from the listing on pages VII and VIII of the *SME Directory Section*, MINING ENGINEERING, July 1959 issue:

Carnegie Inst. of Technology— Pittsburgh, Pa. —The Metals Club. William R. Bitler, *Faculty Sponsor;* Robert F. Mehl, *Dept. Head.*

Case Inst. of Technology—Cleveland —Case Metallurgical Engineering Soc. G. W. Form, *Faculty Sponsor;* A. R. Troiano, *Dept. Head.*

City College of New York—New York—CCNY Student Chapter of AIME. Daniel T. O'Connell, *Faculty Sponsor;* Kurt E. Lowe, *Dept. Head;* James Fox, *Chapter Counselor.*

Colorado School of Mines—Golden, Colo.—Petroleum Student Chapter. David Rowland, *Faculty Sponsor;* James O. Ball, *Dept. Head.*

Cornell University—Ithaca, N. Y.— —Cornell Metallurgical Soc. C. W. Spencer, *Faculty Sponsor;* C. C. Winding, *Dept. Head.*

University of Houston—Houston—Petroleum Student Chapter of AIME. H. L. Overton, *Faculty Sponsor;* C. V. Kirkpatrick, *Dept. Head;* Neal Emory, *Chapter Counselor.*

Lafayette College—Easton, Pa.—John Markle Metallurgy Soc. C. Burroughs Gill, *Faculty Sponsor;* Leon J. McGrady, *Dept. Head.*

Lehigh University—Bethlehem, Pa. Student Metallurgical Soc. R. D. Stout, *Faculty Sponsor* and *Met. Dept. Head.*

Louisiana Polytechnic Inst.—Ruston, La.—Soc. of Petroleum Engineers, AIME Student Chapter. James A. Wasson, *Faculty Sponsor;* Melvin A. Nobles, *Dept. Head.*

Louisiana State University—University, La.—Student Chapter of Soc. of Petroleum Engrs. Benjamin C. Craft, *Faculty Sponsor* and *Dept. Head.*

University of Michigan—Ann Arbor, Mich.—Michigan Metallurgical Soc. C. A. Siebert, *Faculty Sponsor;* Donald L. Katz, *Dept. Head.*

New York University—University Heights, N. Y.—Student Chapter of AIME. Kurt Komarik, Louis Stone, *Faculty Sponsors;* John P. Nielsen, *Dept. Head.*

Ohio State University—Columbus, Ohio—AIME Student Branch. George St. Pierre, *Faculty Sponsor;* Mars G. Fontana, *Met. Engr. Dept. Head.*

University of Oklahoma—Norman, Okla.—Petroleum Engineers Club. W. F. Cloud, *Faculty Sponsor;* John M. Campbell, *Dept. Head.*

Polytechnic Inst. of Brooklyn—Brooklyn, N. Y.—Student Chapter AIME. Victor Franceschini, *Faculty Sponsor* and *Dept. Head.*

Southwestern Louisiana Inst.—Lafayette, La.—AIME Student Chapter. G. G. Varvaro, *Faculty Sponsor* and *Dept. Head.*

Syracuse University—Syracuse, N. Y. Syracuse Univ. Student Chapter of AIME. George Sachs, *Dept. Head.*

A & M College of Texas—College Station, Texas—Petroleum Club. D. M. Bass, *Faculty Sponsor;* Robert L. Whiting, *Dept. Head.*

Wayne University—Detroit, Mich.—AIME Student Chapter. Charles A. Nagler, *Faculty Sponsor;* H. G. Donnelly, *Dept. Head.*

Yale University—New Haven, Conn. Yale Metallurgical Soc. Maur J. Weldon, *Faculty Sponsor;* Wm. D. Robertson, *Dept. Head.*

Personals

Appointment of **A. L. Stewart** as engineer-in-charge of crushing, grinding, and minerals processing machinery has been announced by Allis-Chalmers Manufacturing Co. He has been regional representative in Cleveland since 1955.

Among the past presidents of the American Industrial Hygiene Assn. to be honored for their service was **William P. Yant,** the first AIHA president in 1939. Dr. Yant received a bronze placque in acknowledgment of his 20 years of service to the organization.

A. L. STEWART

W. P. YANT

In recent elections of the board of directors of the National Coal Association. **R. L. Ireland,** chairman of the executive committee of Consolidation Coal Co., was elected vice chairman, and **George E. Enos** continued as treasurer. Mr. Enos is president of Enos Coal Mining Co. A revised charter and new bylaws of the association have been adopted with 35 members elected to the new board of directors. **Frank F. Kolbe,** retiring president, will be a board member ex officio. Regional directors elected for a term of one year are as follows: **H. LaViers; R. L. Ireland; F. Nugent; J. T. Berta; H. V. Fritchman; R. P. Tibolt.** Directors elected for two-year terms are: **C. R. Griffith; M. Eastin, Jr.; H. G. Schmidt; G. E. Owen; R. H. Knode; H. E. Jones; N. Thomas.** The following directors will serve for three years: **K. A. Spencer; W. J. O'Connor; G. Bonnyman; H. C. Woods; G. E. Enos; R. T. Todhunter, Jr.;** and **S. A. Caperton.** Elected directors-at-large for one year are: **R. E. Salvati; F. S. Elfred; H. C. Livingston; D. L. Francis;** and **W. S. Webster.** Those who will serve for a two-year term are: **A. R. Matthews; H. St. Clair; D. W. Buchanan, Jr.; W. H. Ritter; J. L. Kemmerer, Jr.** Three-year directors-at-large are: **J. R. Maust; S. Colnon; S. F. Sherwood; N. H. DeBardeleben;** and **N. E. Kelb.**

The National Academy of Sciences-National Research Council has appointed a committee to determine how materials research and development in the U. S. can be accelerated to meet the increasing demands. AIME members on the committee include **Clyde Williams,** the chairman, **A. J. Herzig, Augustus B. Kinzel, J. D. Morgan, Jr., T. B. Nolan, A. J. Phillips, F. Seitz, C. S. Smith,** and **D. Swan.**

Walter V. Spotte, until recently sales engineer for Joy Manufacturing Co.'s Pittsburgh district office, has been promoted to assistant sales manager, St. Louis territory, with headquarters in Chicago. **Walter G. Hutz** has been assigned to the district vacated by Mr. Spotte, with headquarters in Uniontown, Pa. He has been sales engineer in Huntington, W. Va.

Donald D. Phelps, formerly technologist, U. S. Steel Corp., has been made research engineer for Dravo Corp. in Pittsburgh.

Morson S. Fotheringham received the platinum medal from The International Nickel Co. of Canada Ltd. at the annual dinner of the Canadian Inst. of Mining and Metallurgy in

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PERSONALS: Please list below your former company and title and your new title and company (or new work) for use in MINING ENGINEERING. (Copy deadline for personals items is six weeks before date of issue.)

Name .....

Former Company .....

Former Title ..... Length of Time There .....

New Company .....

New Title ..... Date of Change .....

.....

Any recent activity that would be of interest to members:

.....

.....

Montreal. Mr. Fotheringham became president of Steep Rock Iron Mines Ltd. in 1950.

John Alico has recently been appointed director of engineering for the Walworth Co., responsible for all engineering functions of the valve and fittings manufacturers.

Dorr-Oliver Inc. announced the retirement of **Arthur Terry, Jr.**, as vice president for international administration and as director of the company.

J. ALICO

A. TERRY, JR.

James E. Cleveland of Ingersoll-Rand Co. has transferred from the Knoxville, Tenn. office where he was office engineer, to the El Paso, Texas office where he is now sales engineer.

R. G. Vervaeke has been appointed manager of the Pascagoula Works for H. K. Porter Co. Inc. in Pittsburgh.

D. W. Fuerstenau has left Kaiser Aluminum & Chemical Corp., where he was manager of mineral engineering, to become associate professor of metallurgy in the Dept. of Mineral Technology, University of California at Berkeley.

Mark Lintz, mining and metallurgical engineer of Prescott, Ariz., has returned to his office after two months of examination work in Alaska.

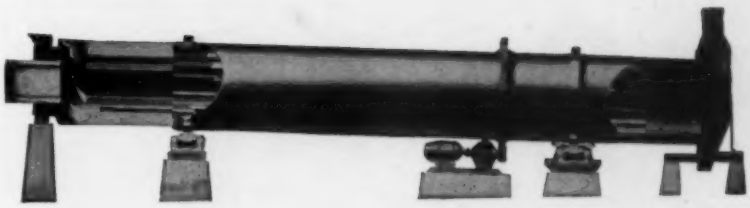
O. C. Rheinheimer is retiring from Cia. Minera de Penoles, S. A., after 30 years of service with the parent company and in Monterrey where he was unit mine manager. His home is in El Paso, Texas.

Rex Hodge has become master mechanic for Stearns Coal & Lumber Co. He had been instrumentman with Louisville & Nashville Railroad Co. in Covington, Ky.

Lisle R. Messer, field engineer for Pacific Foundry Co. Ltd., is in Almaden, Spain, supervising the erection of an additional 250 tpd facility with two Pacific furnaces for the reduction of mercury ores.

Clinton O. Bunn, formerly assistant chief mechanical engineer in the U. S. Army Corps of Engineers, Albuquerque district, has been promoted to chief mechanical engineer and transferred to Fort Belvoir, Va.

Frank J. Chernosky, who has been a research fellow at Michigan Col-



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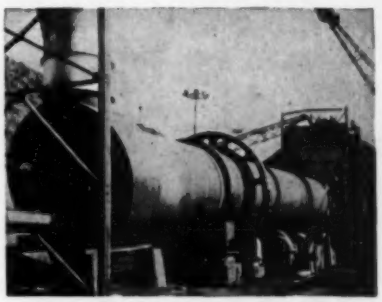

10' diameter, 80' long "XH" Ruggles-Coles Dryer drying bauxite in Jamaica.

Four 80" diameter, 60' long "XH" Ruggles-Coles Dryers handling asbestos ore in Canada.

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personals

continued

lege of Mining & Technology on a USBM fellowship, now is research technologist for Republic Steel Corp. at their research center in Cleveland.

L. E. Montgomery is a computer for Geophysical Services Inc. and has transferred from seismic to gravity crew, working in the marsh and Gulf areas of southern Louisiana. His work includes drafting, computing survey data, contouring maps, handling expense accounts and personnel problems.

Robert R. Guilinger, employed by Union Carbide Corp., has transferred from the Trace Elements Corp. where he was resident geologist, to Globe Mining Co., another unit of Union Carbide, where he will be chief geologist, stationed in Riverton, Wyo.

T. M. WARE

G. F. HALFACRE

Thomas M. Ware, president of International Minerals & Chemical Corp., has been made chief executive officer after 12 years of service. He was named president in 1958. **Louis Ware** will continue as chairman of the board.

George F. Halfacre has been elected vice president in charge of The New Jersey Zinc Co., succeeding **Philip M. Ginder,** who has retired. Mr. Halfacre was general superintendent of the Palmerton plant and manager of manufacturing.

Morely S. Romanuck, formerly geologist for W. S. Moore in Duluth, now is sales engineer with Atlas-Copco Ltd. in Winnipeg, Manitoba, Canada.

Milton A. Lagergren has been appointed project engineer in the Western Mining Divisions Engineering Dept. of Kennecott Copper Corp. at Salt Lake City. His most recent assignment was assistant to chief engineer for Southern Peru Copper Corp. on the Toquepala, Peru project.

Robert K. Young, Western-Knapp Engineering Co., has transferred from San Francisco where he was project manager, to Chicago, to be district construction manager.

Heyward M. Wharton was recently transferred from the Grand Junction, Colo., office of Union Carbide Nuclear Co. to the company's exploration office in Reno, Nev.

William Homer Young, Jr., formerly with Phelps Dodge Corp. as relief crusher foreman, is in Tacna, Peru, starting operations on the Toquepala project for Southern Peru Copper Corp. as primary crushing shift boss.

Lawrence E. Smith, formerly chief geologist for North Range Mining Co., has become consulting engineer with his specialty open-pit, low grade Nevada gold. His address is 5049 Cottonwood Lane, Salt Lake City.

R. A. Chadwick, III, has become assistant professor of geology at Long Beach State College, Long Beach, Calif. He had been senior geologist, Tri-State Mines Unit, for Eagle-Picher Co. in Cardin, Okla.

John W. Barnes was appointed deputy director of the Source Material Procurement Div. at the Grand Junction Operations office of the U. S. Atomic Energy Commission. Mr. Barnes has spent three years as chief of the planning and evaluation branch of the division.

George C. Horak has been promoted to assistant professor in mining engineering at Lehigh University. He had been an instructor and received his M. A. from Lehigh in June.

W. L. Dotson will be shift boss in the Southern Peru Copper Corp. concentrator now being built in Toquepala, Peru. First operations were scheduled to start in August.

Warren H. Westphal, formerly chief geophysicist for Utah Construction Co., now is senior geophysicist at Stanford Research Inst. in Menlo Park, Calif. He had been located in Salt Lake City.

Ellis B. Herrington, Jr., who had been geologist for American Smelting and Refining Co., has accepted the position of assistant geologist at Kennecott Copper Corp.'s operations in Silver City, N. M.

William R. Moliken of Inland Steel Co., was utility foreman until June when he became assistant general heating foreman at the No. 2 coke plant in Calumet City, Ill. He had been in Steger, Ill.

John E. Norton, formerly engineer for The Anaconda Co., retired in June after 35 years, and moved from New York City to Houston, Texas.

Donald J. Frendzel graduated in June from Pennsylvania State University with an M. S. in mineral

economics and began working for the U. S. Bureau of Mines Div. of Foreign Activities as a commodity-industry analyst. He moved from Monroeville, Pa., to Silver Spring, Md.

E. I. RENOUARD

J. ROSENBLATT

Edward I. Renouard, newly-elected vice president in charge of Western Operations, The Anaconda Co., was named chairman of the program committee for the 1959 Metal Mining and Industrial Minerals Convention of the American Mining Congress in Denver on September 14 to 17.

Joseph Rosenblatt, president of The Eimco Corp., was elected an industrial director of the Federal Reserve Bank of San Francisco.

J. F. Sulzbach, formerly specialist 4th class, civil engineers assistant, in the U. S. Army, now is shift boss for the U. S. A. Snow, Ice, and Permafrost Research Establishment in northwestern Greenland where he is working on a tunneling project.

Howard L. Waldron, formerly professor of mining engineering at the University of North Dakota, currently is assistant to the director, Mining Research Laboratory, Colorado School of Mines. He will in addition study for a doctorate in the fall.

Robert I. Davis, geologist for Cia. Minera de Penoles, S. A. for five years, has accepted the post of assistant professor of geology at St. Louis University in Webster Groves, Mo.

Joseph C. Bennett has become a mining engineer for the M. A. Hanna Co. in Hibbing, Minn. He had been a graduate student at Stanford University.

Daniel Habid, formerly student at City College of New York, now is a graduate student and student assistant at the University of Kansas.

Rowland King, mining engineer and metallurgist, retired from active duties last year and has been out of the country since then.

Lewis D. Clark, professor of mining engineering at the University of Wisconsin, is conducting a program of observation and study in the Montana field of Shell Oil Co. to give life to the *Introduction to Petroleum Development* course that he teaches.

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Wilbert J. Trepp, General Chemical Div. of Allied Chemical Corp., has been promoted from assistant manager to manager of mining operations with headquarters in Morristown, N. J.

Enrique Chico Villasenor, who was chief engineer with American Smelting & Refining Co., now is mine foreman for Cia. Minera Asarco, S. A. in Santa Barbara, Mexico.

Enfield B. Bell is now associated with Pato Consolidated Gold Dredging Ltd. and will be in charge of exploration in Brazil for Cia. Exploracao de Minerica Brasilia, a Brazilian subsidiary now being organized. He was formerly employed by Paul Weir Co. in Korea.

Clinton L. Milliken has been permanently transferred to the Chicago office of Kaiser Engineers, Div. of Henry J. Kaiser Co.

Robert L. Lee is with Shell-BP Petroleum Co. of Nigeria on a transfer from Cia. Shell de Venezuela Ltd. He is a safety engineer working with problems of accident prevention in exploration, drilling, and production sites in the Niger Delta where scattered bush roads present constant hazards.

Elliot J. Brebner received an M.S. in mining in February and began work with Pickands Mather & Co. at Hoyt Lakes, Minn. as process development engineer.

William E. Byers, formerly general superintendent for Boone County Coal Corp., now represents Goodman manufacturing Co. as sales engineer in Logan County, W. Va.

W. K. DENNISON

G. D. BELLOWS

William K. Dennison has been appointed mine superintendent in charge of Kaiser Steel Corp.'s coal mining operations at Raton, N. M.

George D. Bellows has been elected a vice president of the Paul Weir Co. Inc. He has been in charge of the Ferrous and Non-Ferrous Mining Dept. in Korea where the firm is supplying technical assistance to the government.

Fred H. Howell, senior geologist with Kennecott Copper Co., transferred from the Braden Copper Co. in Rancagua, Chile, to Salt Lake City, where his home address is 2610 East Milo Way.

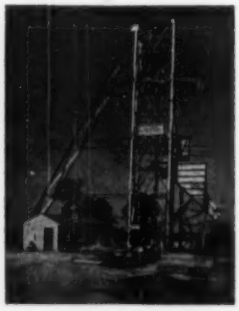
Royale J. Stevens, formerly employed as a metallurgical and smelting specialist in the Western Mining Divs. of Kennecott Copper Corp., has now been appointed general superintendent of the reduction plant at the Chino Mines Divs. in New Mexico.

Paul D. Proctor, chairman of the Geology Dept., Missouri School of Mines, has been doing consulting work for U. S. Steel's Columbia Iron Mining Co. in the western states.

Jon T. Langstaff has become a highway engineer for the U. S. Forest Service at Deschutes National Forest. He had been a student at Missouri School of Mines.

Wilford S. Wright of the International Cooperation Administration, formerly minerals survey advisor in the Philippines, has completed his report there and moved to Iran as a mining engineer.

Jack E. Morris has been appointed general manager of the Container Div., Jones & Laughlin Steel Corp.



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His headquarters are in Pittsburgh. He had been director of product development in the general office.

James A. Williams has been appointed director of the Div. of Mines and Minerals for Alaska. **Richard V. Murphy,** petroleum engineer, is in the Anchorage office along with **Philip R. Woodside,** petroleum geologist.

Edmund G. West has become an engineer with the Eimco Corp. in Salt Lake City. He had been a reporter on the Grand Forks Herald in North Dakota.

Raymond C. Barkley, exploration geologist for Kerr-McGee Oil Industries, transferred from Monticello, Utah, to Albuquerque, N. M.

Joseph B. Elizondo, formerly general superintendent of mines for Eagle-Picher Co., now works for White Pine Copper Co. in White Pine, Mich.

George L. Ziminsky of Atlas Powder Co. no longer is utilities engineer at the Reynolds plant, but is purchasing agent in Wilmington, Del.

F. R. TOOTHMAN

B. C. BERRY

Fred R. Toothman has been appointed engineer of coal properties with headquarters at Huntington, W.Va., for the Chesapeake and Ohio Railway. In 1958 he had been promoted to administrative assistant engineer.

Bernard C. Berry, chairman of the board of directors of the Allen-Sherman-Hoff Co., has retired from active management duties. He will continue with the firm in a consulting capacity.

Richard L. Osler, who had been project engineer for Universal Atlas Cement Div. of U. S. Steel Corp., now is general manager of Caribbean Cement Co. in Jamaica, B.W.I.

E. E. Hawley, formerly vice president and manager of Trans-Pacific Metals Inc., now is a mining consultant specializing in property inspection, development, and management, in Sausalito, Calif.

Donald M. Forsman has accepted the position of assistant metallurgical engineer with Chile Exploration Co. in Chuquicamata. He had been assistant research engineer for Anaconda.

James W. Coulon has become assistant to mine superintendent of

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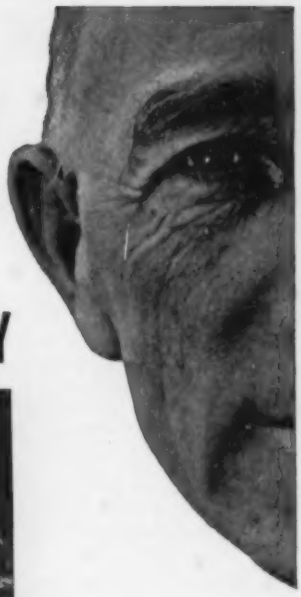

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Westvaco Chlor-Alkali Div., Intermountain Chemical Co., after two and a half years with the United States Fuel Co. as mine planning engineer. He is located in Green River, Wyo.

John M. Bratt, formerly student at the University of Minnesota, has accepted the position of mining engineer for Oliver Iron Mining Div. of U. S. Steel, in Hibbing, Minn.

Bert W. Thomsen graduated from South Dakota School of Mines and Technology in June and is living in Montebello, Calif.

R. H. Hughes, president of Clinchfield Coal Co., has accepted the chairmanship of the program committee for the 1960 Coal Convention of the American Mining Congress.

Parke A. Hodges, vice president of Behre Dolbear & Co., is conducting a mineral reconnaissance in Haiti.

H. C. Gunning, formerly dean of applied science at the University of British Columbia, now is consulting geologist for Anglo-American Corp. of South Africa, Ltd. acting as consulting geologist in Salisbury, Rhodesia.

Charles F. Herbert, who had been a partner in Yukon Placer Mining Co., now is self-employed as a consulting engineer doing placer examinations in Canada and South America, and copper deposits in Alaska.

J. Gary Mitton, who had been promoted from metallurgist-ore dressing to senior metallurgist-concentrating department for Cerro De Pasco Corp., has been in San Felipe, Chile, during April, May, and June, carrying out pilot concentration tests on the new Rio Blanco orebody. He also observed the operations at Chuquicamata and Braden in Peru.

Guy E. Ingersoll retired in June as associate professor of mining and metallurgy at Texas Western College. He is now engaged in consulting work in mining engineering.

Richard V. Wyman, vice president of Western Gold and Uranium Inc., has organized the new firm Intermountain Exploration Co. for consulting and exploration work in iron and other metals in the western states.

G. H. HARRIS

F. A. BRINKER

The appointment of **Guy H. Harris** to the position of associate scientist for the Dow Chemical Co. has been announced. Mr. Harris had been project leader at the Western Div. research laboratories.

Fred A. Brinker was named general manager, Western Div., of Vanadium Corp. of America. He was formerly chief metallurgist.

R. G. Pinkerton left his position as junior mine engineer with Potash Co. of America and joined Boyles Bros. Drilling Co. as mining engineer. He is located in Salt Lake City.

R. V. Taborelli has been promoted to the rank of Captain in the U. S. Naval Reserve. He is head of the engineering department of the Lovelace Foundation for Medical Education and Research at Albuquerque, N. M.

N. A. Whittaker has been actively engaged in mining and prospecting in Montana in the Running Wolf Creek iron deposits. During the winter he will be developing several high grade iron ore properties in California.

Robert E. Swain, center, has been awarded the Frank A. Chambers Award, established by the Air Pollution Control Assn., for his special contributions to the science. John F. Barkley, right, received the Richard Beatty Mellon award for "the successful control of air pollution in the nation's capital" for the U. S. Bureau of Mines. Shaking hands with Mr. Swain at left is Milton Reizenstein.

Jerry M. Whiting, assistant editor of *Mining Congress Journal*, has resigned to accept the position of assistant professor of mining engineering at the University of Idaho's College of Mines in Moscow, Idaho.

Sim S. Clarke, Baxter Springs, Kan., has been reappointed to The Mineral Industries Council of The Kansas State Geological Survey.

N. A. WHITTAKER

J. M. WHITING

Teams working with the Montana Bureau of Mines and Geology have undertaken a number of field projects during the summer. **Frank A. Crowley** visited small mines to gather data for the 1959 directory. **Uuno M. Sahinen** and **Ralph I. Smith** continued their project on clay and shale deposits. **R. G. McMurtrey** and **R. L. Konizeski,** under the supervision of **F. A. Swenson,** district geologist, have been conducting a study of the geology and groundwater resources of Powell and Deer Lodge Counties. This study and another by **E. A. Zimmerman,** in Hill and Blaine counties, are in cooperation with the USGS. Mr. Zimmerman will also be studying Judith Basin and Fergus counties. **V. E. Gwinn** has been studying the structure of the Northern Flint Creek Range and Dunkleburg mining district for his doctoral thesis. **D. N. Rubel** has been investigating volcanic rocks of Park county, also for a doctoral thesis. Montana limestones were analyzed by **Thomas J. Cash. Willis M. Johns** and two summer assistants, **Lawrence Beer** and

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D. M. Hutchinson have been working on mineral resources in the northwestern part of the state. **Kenneth F. Fox, Jr.**, was assigned the study of geology in the Mill Creek Basin, a little known area, and his field work was scheduled for completion in September.

The Maine Geological Survey has announced the appointment of **Robert G. Doyle** as its new state geologist. Mr. Doyle came to the Survey last year as assistant to the state geologist, John R. Rand, recently retired.

Robert B. Aitchison, the engineer who developed the jet-piercing flame process to obtain a new source of iron ore from hard rock, will receive a John Price Wetherill Medal from The Franklin Institute in October. Mr. Aitchison is consulting engineer for Linde Co., Div. of Union Carbide Corp.

R. G. DOYLE

R. B. AITCHISON

Howard B. Nicholas, formerly associated with the Ames Laboratories of the Atomic Commission, has joined Hawley & Hawley Inc. as chief chemist and laboratory manager.

Charles E. Schwab has been named general manager of Kellogg operations of The Bunker Hill Co., effective Jan. 1, 1960. Mr. Schwab is presently assistant to the president and chairman of the industry's Emergency Lead-Zinc committee.

Denver Equipment Co. announces sales staff changes for added service. **James E. Quinn,** who has been sales engineer in the Western Div., has been promoted to manager of the division. **Clyde V. Johnson,** who has served as assistant sales manager, has been promoted to manager of the Central Div. **H. J. Gisler,** chief metallurgist, becomes manager of the Eastern Div. **Harold W. Harrah,** formerly sales engineer in the Domestic Sales Div., has been transferred to the International Sales Div. **Richard W. Flagg,** assistant director of the Denver Ore Testing Div., will now be chief metallurgist. And **Norman L. Johnson,** sales engineer, Eastern Div., has been transferred to his new responsibilities in the International Sales Div.

Justo B. Bravo has been named group leader, new products and processes, for the Foote Mineral Co. **Meyer M. Markowitz** advances to group leader of the thermodynamic and physical chemistry group. **Lawrence J. Reader** has been promoted to group leader of technical services. All three are in Berwyn, Pa.

Frank W. Bowdish, who was senior chemical engineer at the Colorado School of Mines Research Foundation until August, has accepted the position of professor of metallurgy and head of the department of mining and metallurgy at New Mexico Inst. of Mining and Technology, Socorro, N. M.

Arthur E. Poole has been appointed to the sales-engineering staff of the Filter Div., The Eimco Corp. He had been with Commercial Filters Corp. as chemical engineer. His home is in Linden, N. J.

H. J. GISLER

H. B. NICHOLAS

The expanding staff of the Colorado School of Mines Research Foundation includes the following additions: **W. Chris Spence,** formerly general mill foreman at the Andes Copper Mining Co. in Chile; **Manuel de Losada,** formerly mill superinten-

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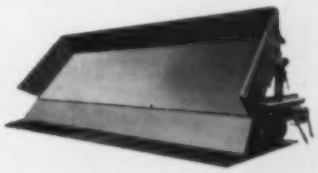

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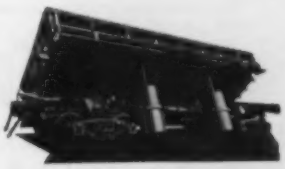

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personals

continued

dent at Cerro de Pasco Copper Corp. in Peru; **Warren H. Yarroll,** formerly mill superintendent at Texas Zinc Minerals Corp. operations in Mexican Hat, Utah; **William P. White,** research engineer with the Dow Chemical Co.; **M. E. Defoe,** formerly mill superintendent at the Chelan Div., Howe Sound Co.; **Paul Smith,** who was assistant mill superintendent at Fredericktown, Mo. for National Lead Co.; and **Harold W. Miller**, formerly Technical Director of the Wah Chang Corp., Boulder Colo.

Robert H. Stebbins, formerly geologist with the Raw Materials Exploration Div., Columbia Iron Mining Co., U. S. Steel Corp., has joined the staff of Hunting Technical Services Inc. in New York, as chief geologist.

George W. Boulter has been appointed assistant manager of the mining division of Marion Power Shovel Co. He had been safety director, Montana State Highway Dept.

Frank L. Gaddy was recently employed by the Chesapeake & Ohio Railway Co. as mining engineer in the coal development office at Huntington, W. Va. He spent the last six years with the U. S. Bureau of Mines in Norton, Va.

R. H. STEBBINS

G. W. BOULTER

Robert M. Hansen has been appointed business development engineer for the Western-Knapp Engineering Co. and will be located in Salt Lake City. Mr. Hansen has been with Western Machinery Co. as sales manager.

F. L. GADDY

R. G. BOTTORF

Robert G. Bottorf has been appointed sales manager of the Colmar, Pa., plant of Link-Belt Co. He is a materials handling specialist and a designer of the company's Philadelphia plant.

Byron K. Hartman has been appointed executive vice president and general manager of Syntron Co. He had been sales manager of the Colmar plant of Link-Belt Co.

R. M. HANSEN

B. K. HARTMAN

E. L. Clark has been appointed director of the Department of Natural Resources, State of Colorado. Mr. Clark has been associated with Four Corners Oil & Minerals Co. since 1955, being responsible for the exploration and development programs for the company. Previously he was state geologist of Missouri.

Frank W. Chambers has been named executive vice president of Strategic Materials Corp., Buffalo. He was formerly director of engineering for Kennecott Copper Corp.

James W. Minette, formerly a student at the Colorado School of Mines, now is mining engineer for U. S. Borax & Chemical Co. in Boron, Calif.

Kenton E. McElhattan has been appointed product manager, miners and loaders, for Joy Manufacturing Co. Other new appointments include **Edwin C. Cooney** as manager, hoist and loader department, and **Bryan J. Dickinson,** manager, tungsten carbide bit department. The latter two men will be in Claremont N. H. while Mr. McElhattan will be in Franklin, Pa.

H. Eugene Mauck, who was general manager of Olga Coal Co., now is vice president of operations for Freeman Mining Corp. in Chicago. Mr. Mauck, who is Coal Division program chairman for 1959 and 1960, moved from Coalwood, W. Va.

Obituaries

Jon S. Mayer (Member 1950) was killed in an automobile accident on May 30, 1959. He had attended the Michigan College of Mining and Technology from 1951 to 1955. He was born in New York and lived on Long Island.

Henry B. Parfet (Member 1946) died on May 29, 1959. He was manager of the South American Gold and Platinum Co. in Columbia. His career in mining took him to Peru, Chile, Bolivia, and the Philippine Islands. Born in Golden, Colo., he attended the University of Michigan and the Colorado School of Mines.

Chester H. Steele (Member 1916) vice president in charge of western operations for The Anaconda Co., died on May 19, 1959. Mr. Steele began his long association with Anaconda in 1916, the year he graduated from the Montana School of Mines. He headed the Butte geological department from 1948 until 1952 when he was made general manager of western operations. He was a past chairman of the Montana Section and held many positions as director and president in community and industry life.

Andrew W. Tolonen (Member 1920) died on Apr. 11, 1959. He had been a mining engineer for The Anaconda Co. for the past nine years. Born in Michigan, he attended the Michigan College of Mines, receiving B.S. and E.M. degrees. He began as an underground laborer and then became engineer for the Kennecott Copper Corp., in Alaska. He worked for several firms in South America, Canada, and West Africa.

Charles W. Wheelock (Member 1920) who was born in Ohio, and worked in New York, passed away on May 30, 1959. He was working, leasing, and examining mines in 1895 and became general manager of Engineering Co. of America in New York in

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1905. His consulting work took him to South America, Europe, and on examinations all over North America.

Worthen Bradley (Member 1929) native of San Francisco and active member of the San Francisco Section, recently passed away. He graduated from the University of California and began as assistant surveyor at Spanish mine, Nevada Co., and then as mucker for Atolia Mining Co. In 1927 he was superintendent of Eagle Venture, Panamint Valley, and then general superintendent of Sulphur Bank mine, where two years later he became manager. Beginning in 1933 he was president of Bradley Mining Co. of San Francisco.

Leo H. Glanville (Member 1943) died on June 2 at his home in Camarillo, Calif. He had been Climax Molybdenum Co. (now American Metal Climax Inc.) ventilation engineer and safety director.

Viggo Harms (Member 1956), process engineering specialist, died on May 27, 1959. He had been a member of the Dorr-Oliver Inc. staff for more than 33 years in the Plant Engineering Div. He graduated from the Polytechnical College of Copenhagen and joined the Dorr-Oliver subsidiary in Germany in 1926. He transferred to the Hague in 1932 and came to the U. S. parent company plant in 1941.

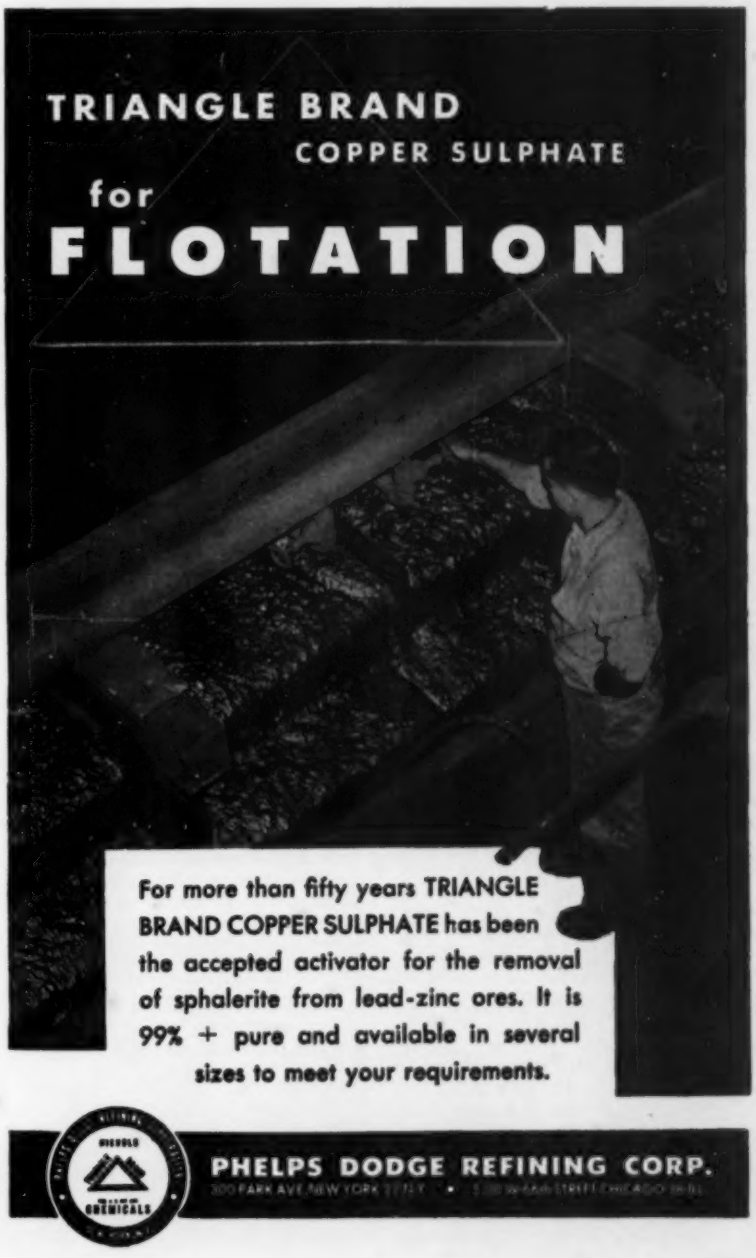
Frank H. Hayes (Member 1913), former member of the War Production Board, died on March 29, 1959. He was born in Chicago and educated at Columbia University, receiving an E.M. degree in 1909. He worked for the Detroit Copper Co. in Morenci, Ariz., and in 1920 became assistant to the vice president and general manager of Phelps Dodge Corp. In 1922 he was superintendent of mines at Copper Queen Branch, Bisbee, Ariz. After his war service for the government he was appointed chief of the metals and minerals division of the National Production Authority.

Clifford Hoag (Member 1930) passed away on Apr. 30, 1959. Born in Michigan, he received B.S. and E.M. degrees from the Michigan College of Mines and began his career with Shannon Copper Co. in Clifton, Ariz. He held a variety of positions from surveyor and shift boss to chief engineer and superintendent with this firm, then joined Miami Copper Co. and The Mexican Corp. Ltd. In 1930 he was mine superintendent for the American Metal Co. in New Mexico. Later his career took him to the Ashanti Goldfields Corp. Ltd. in West Africa.

William M. Keay (Member 1953), born in Chile, passed away in Hong Kong on Mar. 19, 1959. He was educated in England at Dulwich College and University College, receiving a B.Sc. in 1921. He was a mine safety engineer, a consulting mining engineer, and in 1915 superintendent of mines to the Government of the Colony of Hong Kong.

Malcolm B. Kildale (Member 1940), Utah geologist, died June 13, 1959. He had been chief geologist for International Smelting and Refining Co. since 1942. He graduated from Stanford University and went on to Columbia University for M.A. and Ph.D. degrees. For a few years he was a lecturer on mineralogy at Columbia and a professor of economic geology at Stanford.

Milton S. Lindholm (Member 1917) passed away from a heart attack at the home of his daughter in Encino, Calif., on June 12, 1959. Mr. Lindholm was born in Ortonville, Minn., and was graduated from the University of Minnesota School of Mines in 1911. He worked in Leadville, Colo., for one year and spent one year in Bisbee , Ariz., before leaving for the African Congo. There he prospected for diamonds for the Ryan-Guggenheim group, under the supervision of the late Sydney H. Ball. When World War I broke out he returned to Arizona where he joined the 109th Engineers, and served in France. In 1919 he returned to Bisbee where he joined the geological staff of the Calumet and Arizona Mining Co.,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serving as chief geologist for several years before the merger with the Phelps Dodge Mining Co. Upon his retirement in 1952, he was chief geologist for the Copper Queen Branch of Phelps Dodge. He was an active community worker, and moved with his wife to Santa Monica, Calif., in 1954, to set up a home.

Henning Marstrander (Member 1939), mine inspector, was accidentally killed near Helena, Ala., on Mar. 31, 1959. He had been inspector for the USBM in the Birmingham district for the last 14 years. Born in Denmark, he was educated there and at Columbia University, receiving his engineer of mines degree from the Norwegian Institute of Technology in 1917. He worked in various capacities for the Norwegian government. In 1921 he was a mining engineer in Uniontown, Pa., where he later began work for the USBM. He also worked in Denmark and in Iran and was the author of several safety articles.

Hubert Raymond Banks (Member 1946), former senior metallurgist for the Consolidated Mining & Smelting Co., died on Feb. 4, 1959, in Ottawa, Ont., Canada. Born in Toronto, he graduated from the University of Toronto in 1914 and went to Arizona for Consolidated Arizona Smelting Co. as mill operator. He spent three years in the Canadian Engineers in France, returning with rank of Captain, and in 1924 joined the firm he worked for most of his life. He was closely associated with flotation process applications, and helped develop the first tin recovery in Canada.

Stuart A. Falconer (Member 1945), chief metallurgist for American Cyanamid Co., died at the Stamford, Conn., hospital on Apr. 25, 1959. He was 60 years old. He graduated from the University of British Columbia and did graduate work at Columbia University. He served in the Canadian Army during World War I and joined American Cyanamid in 1927.

Lawrence Henderson (Member 1957) died on Apr. 24, 1959. He was born and raised in Alabama, attending Polytechnical Inst. and starting work with Tennessee Coal Iron & Railroad Co. in Birmingham. He worked there for 13 years, the last eight as foreman in the coal mines. In 1941 he joined Republic Steel Corp. and in 1946 he was with Alabama Power Co. as safety supervisor at Gorgas, Ala.

Marvin J. Udy (Member 1918) passed away on April 11, 1959. A native of Utah, he received B.S. and M.S. degrees from the University of Utah where he was a Fellow in metallurgical research. In 1916 he was assistant research chemist for U. S. Smelting Co. and in 1918 he moved to Niagara Falls, N. Y., as chemist for Hooker Electrochemical Co. His many other endeavors included the development of Udylite Process Co., and special work on chromium plating. From 1937 on he was vice president of Chromium Mining and Smelting Co., Saulte Ste. Marie, Ontario, in charge of research and development.

William D. Van Dyke, Jr., (Member 1940), president of the Mineral Mining Co., died at his home in Fox Point, Wis., Apr. 29, 1959. He was also a director of this controlling firm for mining interests of the Van Dyke family in Upper Michigan. In addition he was a trustee of the Northwestern Mutual Life Insurance Co. He graduated from Princeton University in 1917 and entered the Army, serving as field artillery Captain in Europe during World War I.

Frank W. Woodman (Member 1953) died on Mar. 15, 1959. He had been born in Iowa and graduated from South Dakota School of Mines with a B.S. degree in metallurgy. He worked for Columbia-Southern Chemical Corp. as superintendent, and was a consultant for Vanadium Corp. of America. He held several positions as superintendent, and studied the magnesium process in Manchester, England, for a plant in Henderson, Nev. of Basic Magnesium Inc. After a year with the U. S. Bureau of Mines he joined The Anaconda Copper Mining Co. in the research department.

Edward L. Young (Member 1918) passed away on May 6, 1959. Born in Los Angeles, he graduated from the University of California in 1899. From 1905 to 1916 he was superintendent of the Hazel Gold Mining Co. in California, and for the next 16 months he was field engineer for U. S. Smelting, Refining & Mining Exploration Co. In 1918 he was working for the U. S. Bureau of Mines making chrome investigations.

Edgar Stuart Ward (Member 1953) died on Feb. 27, 1958. He was born and educated in Philadelphia and began his mining career as an engineer for the Highway Bureau of that city. He received a commission in 1917 from the Mexican Coal and Coke Co., Las Esperanzas, Mexico, and stayed for another assignment when his report was complete, then working for New Sabinas Coal Co. Ltd., and American Metal Co., all in Mexico. He returned to Philadelphia in 1925 to work for several construction companies.

William H. Watters (Member 1954) died Dec. 6, 1958. Born in Vancouver, Wash., he attended Oregon State College, graduating in 1916. He began work as a surveyor, then served in the Army in the U. S., France, and England as master engineer. In 1919 he was shift boss in a lead refinery, Bunker Hill & Sullivan smelter, in Kellogg, Idaho. He traveled from Arizona to Bolivia. to San Francisco and New York in various positions including acting assistant manager of Yukon Gold Co. Federated Malay States. For a while he was self-employed, operating a small gold placer in California. In 1937 he was general superintendent simultaneously of three dredging companies, with offices in San Francisco. And in 1954 he became president and director of field operations for Amuranium Corp.

Sidney L. Wise (Member 1914) died on Feb. 28, 1959. He had been born in Baltimore and educated at Columbia University School of Mines, receiving an E. M. degree in 1911. He began as assistant engineer for Suriana Mining & Smelting Co., in Mexico, for one year, then was an engineer for Mines Management Co. of New York, occupied principally with examination work. He had his own financial consulting business in New York for many years.

Edgar M. Barker (Member 1937) vice-president in charge of production for Calaveras Cement Co., died on Mar. 19, 1959. Born in Globe, Ariz., in 1909, he received a B.S. degree from the University of Utah in 1931 and spent the following two years as underground surveyor for the Union Corp., Springs, Transvaal, South Africa. He then worked in Northern Rhodesia, returned to California in 1936, and has been with Calaveras since 1947.

Marc E. De B. Remy (Member 1947) died in January 1959. He was born in Brussels, Belgium, and attended Louvains University Mining School. He worked for several firms in England, France, and Germany, and was director and manager of Remy & Co., Belgium Works in Europe and Argentina. In 1922 he became general manager of the firm. Nine years later he resigned to become independent and worked in a private research laboratory in chemistry, geophysics, and geology. From 1938 onward he staked different mines and claims in Abitibi, Canada.

Patrick E. Green (Member 1935), born in Spokane in 1914, passed away in 1958. He graduated from the University of Washington and gained mining experience in California, Montana, and Washington. He was superintendent of Cuban properties, Harbison & Walker Refractories, and superintendent of mines for International Mining, Grace y Cia., Bolivia.

Lionel M. Hartvigsen (Member 1954) was born in Sandy, Utah in 1896, and recently passed away. He had been living in Midvale, Utah,

where he was chief clerk of the Midvale plant.

Thayer W. Saylor (Member 1945) died on April 7, 1959. He had been born and educated in Kansas, graduating from the University of Kansas in 1927. He had worked for International Smelting & Refining Co. in various positions progressing to assistant superintendent of the copper plant.

John C. Steward (Member 1945), formerly of Plano and Aurora, Ill., whose last address was Canon City, Colo., died Feb. 4, 1959, in California. He was educated at the Colorado School of Mines and worked in Illinois, Iowa, Colorado, Utah, and Washington. His many jobs included mining, banking, and cost accounting, work with the USBM and the Bonneville Power Administration.

Stephen Szeli (Member 1955) was born in Hungary in 1902 and died recently. He was educated in the Royal Hungarian School of Forestry and was a mining engineer of Komlo mines of the Hungarian Industry Ministry. In 1940 he became chief manager of the mines and in 1944 was the chief counsellor, controlling the Hungarian American oil industry order of the Ministry. In 1948 he escaped from Hungary and made professional reports for the U. S. Army concerning the Hungarian coal and oil situation. He worked next in Switzerland in a machine tool work factory, then was planning engineer at a coal mine in Greece. On his arrival in the U. S. he worked as control chemist of Borax mine in Boron, Calif.

Membership

Proposed for Membership

Society of Mining Engineers of AIME

Total AIME membership on Aug. 31, 1959, was 32,615; in addition 2,738 Student Members were enrolled.

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The Institute desires to extend its privileges to every person to whom it can be of service, but does not desire as members persons who are unqualified. Institute members are urged to review this list as soon as possible and immediately to inform the Secretary's office if names of people are found who are known to be unqualified for AIME membership.

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CHANGE OF STATUS

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REINSTATEMENT

Member

Waldemar I. Konkoff, Burlingame, Calif.

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Necrology

Date Elected	Name	Date of Death
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1949	Ralph B. Utt	July 21, 1950

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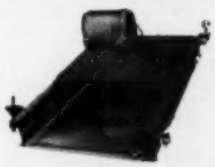

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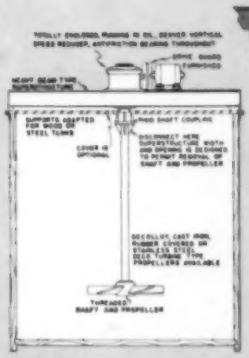

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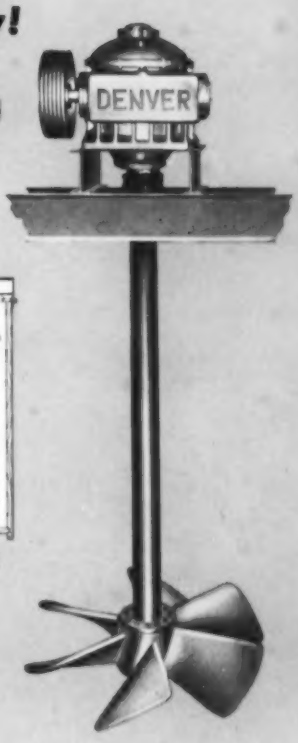

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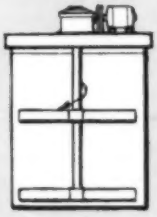

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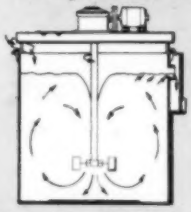

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